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EDITORIAL NOTES.

THE Editors have no doubt that readers would attribute to its true cause the remarkable lateness in appearance of the October number of the Magazine. The reason, of course, was the railway strike, which upset the mails at the period of the month most critical from the editorial point of view. One set of proofs took no less than nine days in transit from printer to editor and after that had to be sent to the authors and returned. Besides the delay, another consequence followed, namely, that the final contents of the number were not at all what the Editors originally designed them to be. After much waiting for delayed proofs, it was finally decided to make up the number from what material was ready, regardless of the traditional plan; this accounts for the absence of any Reports and Proceedings or Reviews in that number. It was hoped to give abstracts of papers read at the British Association and a portion of the Presidential Address to Section C, but fate willed otherwise and the final result was a number almost entirely composed of original papers, which is quite contrary to the usual practice. This procedure will not, it is hoped, be taken as a precedent, and every endeavour will be made in future to maintain the established features of the Magazine, so far as the disturbed conditions of the time allow.

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HEARTY congratulations to Sir Norman Lockyer, K.C.B., F.R.S., who on November 4 will, as editor, issue the "Jubilee" Number of *Nature*, which he commenced in 1869. The Editor of the GEOLOGICAL MAGAZINE was present amongst his numerous friends at the "sending off" dinner given by Mr. Macmillan, the publisher of this worldwide serial, which will on November 4, 1919, issue its 2,600th weekly number. This journal embraces in its pages information on every branch of natural knowledge during the past half-century. Long may *Nature* flourish, and may its editor and publisher still share the continued prosperity of this cosmopolitan and successful scientific weekly.

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WE feel sure that all those geologists who make use of the library of the Geological Society will hear with much regret that Mr. C. P. Chatwin has resigned his post as Librarian to the Society in order to take up a teaching appointment at Liverpool University. Mr. Chatwin came to Burlington House in May, 1913, and soon won golden opinions in every quarter, both on account of his wide

knowledge of geological literature and his unfailing courtesy and helpfulness to those in search of information. During the War, owing to the depletion of the staff he took on his shoulders the principal weight of the Society's business, attending to many of the duties which ordinarily devolve on other officials, in addition to heavily increased work in the Library, largely owing to the demands of the naval and military authorities for maps and publications dealing with the geology and geography of the various theatres of war. Mr. Chatwin leaves Burlington House with the hearty good wishes of his colleagues and friends for his future prosperity in his new sphere of work, which will doubtless give him opportunities of continuing and extending the researches in palæontology on which he has long been engaged.

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The annual course of twelve lectures on geology under the direction of the Swiney Trustees and in connexion with the British Museum (Natural History) will be given by Dr. J. D. Falconer, the subject being the Geology and Mineral Resources of the British Possessions in Africa. The lectures will be given in the Theatre of the Imperial College of Science (Royal College of Science, Old Building), Exhibition Road, South Kensington, on Mondays, Wednesdays, and Fridays, at 5.30 p.m., beginning Monday, November 10, and ending Friday, December 5. The lectures will be illustrated by lantern slides and admission is free. We cannot afford space to reproduce the whole of the interesting syllabus, but the following dates and titles of the lectures may be found useful. November 10, The Continent of Africa. November 12, 14, and 17, The Union of South Africa. November 19, Bechuanaland and British South-West Africa. November 21, Rhodesia and Nyasaland. November 24, Uganda, British East Africa, and Somaliland. November 26 and 28, Egypt and the British Sudan. December 1 and 3, British West Africa. December 5, Summary and Conclusion.

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Two important geological collections of more than local interest have recently been acquired by the Hull Municipal Museum, viz. the Drake and Bower Collections. The first was formed by the late H. C. Drake, F.G.S., who spent many years in the Scarborough district, and also collected largely among the Saurian and other vertebrate remains of the Oxford Clay in the Peterborough area. Mr. Drake was an exceptionally keen and patient collector and was very successful in extracting difficult specimens from their matrix. From the Oolites of the Scarborough and Malton districts he obtained a remarkably fine series of fish and reptilian teeth and bones, some being of altogether exceptional interest. He also carried out original work among the Cephalopods. Many additional records to the fauna of these rocks have been made as a result of Mr. Drake's researches. He was also successful in securing many important vertebrate remains from the Chalk of North Lincolnshire, which have been described in the Palæontographical Society's memoirs, the Geological Magazine, the *Naturalist*, and other

publications. Some years ago he considerably augmented the geological collections in the Hull Museum, several cases being entirely occupied by his gifts. He also assisted in preparing the catalogues of this collection. The specimens recently obtained will be shown with his other fossils in due course. The other collection was formed by the Rev. C. R. Bower. Many of the specimens are described and some figured in his paper on "The Zones of the Lower Chalk of Lincolnshire" in the Proceedings of the Geologists' Association for 1918. This collection consists of over a thousand excellently cleaned Chalk fossils, carefully labelled and localized, including many of those which have been figured in his paper, as well as one of the two known examples of *Actinocamax Boweri*, the other specimen being in the British Museum. The collections are largely from the Lower Chalk of Lincolnshire and from the Chalk of Yorkshire, and there is an interesting series from the Upper Cretaceous of Dover, Folkestone, Kent, and Norfolk. Most of these specimens have been examined and verified by Dr. A. W. Rowe and Mr. C. Davies Sherborn.

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The Cambridge University Press will shortly publish a new work by Mr. J. Y. Buchanan, whose earlier volumes of scientific and other papers are well known. It is entitled *Accounts Rendered of Work done and Things seen*, and consists of a variety of papers on geographical, oceanographical, and other subjects, such as "The Colour of the Sea", "The Sperm Whale and its Food", "Air-tight Subdivision in Ships", "The Daintiness of the Rat", etc.

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Mr. Frederick Chapman, A.L.S., has been appointed part-time lecturer and demonstrator in palæontology at the University of Melbourne. He will take up his duties in March, 1920.

Imperial Mineral Resources Bureau.

With reference to the announcement of the Minister of Reconstruction that the Imperial War Conference, after considering the report of a Committee of which Sir James Stevenson, Bart., was chairman, had made a recommendation in favour of the constitution of an Imperial Mineral Resources Bureau, this body was set up and charged with the duties of collecting information regarding the mineral resources and metal requirements of the Empire, and of advising the various Governments and others concerned from time to time what action might appear to be desirable to enable those resources to be developed and made available to meet the requirements of the Empire.

In accordance with this recommendation the Governors of the Bureau were appointed, one by the Home Government (whose representative is the Chairman of the Bureau), one by each of the five self-governing Dominions, one each by the Government of

India and the Secretary of State for the Colonies, while six representatives of the mineral, mining, and metal industries were appointed by the Minister of Reconstruction after consultation with the principal Institutes and Institutions representing those industries.

Pending the grant of the Charter to the Bureau, the Governors lost no time in laying the foundations of their work and organization. Four Committees of Governors were appointed to deal with :—

1. Intelligence and Publications,
2. Research and Development,
3. Legal Matters,
4. General Purposes and Finance,

and the further scope and development of the Bureau were outlined and decided upon.

The Governors have now received their Charter of Incorporation, and at the moment are busily engaged in putting into effect their scheme of organization.

Correspondence has been entered into between the Bureau and the Overseas Governments of the Empire, with a view to obtaining at an early date all possible information affecting the mineral and metal industries of the countries concerned. In addition certain statistical information on this subject from foreign countries is being obtained through the Foreign Office.

The Governors look forward, when the information is available, to issuing from time to time various statistical and other publications which will be of the greatest service to those engaged in the mineral and metal industries, and it will be one of the chief aims of the Bureau to issue this information as soon as it is available.

In order that the Bureau may be able successfully to discharge its functions, and issue information of an up-to-date character, the Governors are seeking the closest co-operation and assistance of the various Government Departments, Scientific Institutions, Societies, and other bodies with which the Bureau hopes to be associated.

It is the intention of the Governors at an early date to arrange for the co-option on committees of representatives of the various Government Departments, Scientific Institutions and Societies, as decided upon at the Conference which was held at the Home Office on the 14th day of February, 1919, the object aimed at being the consideration of the best means to be adopted to bring about the co-operation between the various agencies that is so much desired, and to deal effectively with special branches of the mineral and metallurgical industries.

The offices of the Bureau are at 2 Queen Anne's Gate, S.W. 1, and all communications should be addressed to the Secretary.

ORIGINAL ARTICLES.

I.—The Magnesian Limestone of Durham.

By David Woolacott, D.Sc. F.G.S.

(PLATE XII.)

Part II.

The Divisions of the Limestone—The Thrusting in South-East Northumberland and North-East Durham—The Breccias.

1. Divisions of the Magnesian Limestone of Durham.[1]

<table>
<tr><th></th><th>East.[2]</th><th></th><th>West.</th></tr>
<tr><td>Upper Red Beds.</td><td colspan="3">Marls, red marly false-bedded sandstones, thin fossiliferous dolomitic limestones, and beds of salt, anhydrite, and gypsum, 300 feet (only occur in South Durham).</td></tr>
<tr><td rowspan="4">Upper Limestones.</td><td colspan="2">Oolites (originally gypsiferous) of Roker and Hartlepool, 100 feet.</td><td>Gypsiferous oolites (proved by boring in South Durham).</td></tr>
<tr><td colspan="2">Concretionary limestone, 250 feet of bedded concretionary dolomitic and calcareous rock.</td><td rowspan="3">[3]</td></tr>
<tr><td>12 feet.</td><td rowspan="2">Unbedded dolomitic and calcareous shell-bank of Bryozoa Reef, over 300 feet.</td></tr>
<tr><td>Yellow-bedded dolomitic and segregated limestones, 150 to 200 feet.</td></tr>
<tr><td>The Flexible Limestone.</td><td></td><td></td><td rowspan="2">Segregated limestones.
Dolomitic limestone.
Dolomitic oolite.
Granular oolite.
Fossiliferous dolomite.[4]
240 feet.</td></tr>
<tr><td>Middle Limestones.</td><td></td><td></td></tr>
<tr><td>Lower Limestones.</td><td colspan="3">250 feet of bedded yellow dolomites and dolomitic limestones, with which are interbedded in the south of the county lenticles of grey calcareous limestone. These beds thin out rapidly to the north of Sunderland.</td></tr>
</table>

[1] Gypsum and anhydrite were probably present on all horizons, as proved by their presence throughout the limestone in the Seaton Carew boring. The Lower Limestones were probably the least gypsiferous, the eastern equivalents of the reef the most, while the segregated and concretionary rocks were in all likelihood impregnated with gypsum, and the hollow oolites of Roker and Hartlepool were originally gypsiferous.

[2] East and west refer to east and west of the reef.

[3] The exact nature of the original Upper Limestones is as yet unknown to the west of the reef. They are totally denuded north of a line drawn through Hartlepool. They have been passed through by borings in South Durham, but nothing very definite can be gathered from the description of these. The Upper Red Beds occur to the west of the reef, and the Upper Limestones are gypsiferous and in part oolitic. The concretionary limestones probably do not occur, being represented by gypsiferous rocks.

[4] Maximum proved thickness as obtained in the Sheraton and Cotefield Close borings. These beds are largely denuded in North Durham and in the south of the county are covered by drift.

The Lower Limestones reach a thickness of over 250 feet in the south of the county, and usually appear as a series of bedded dolomites or dolomitic limestones, with which are interbedded lenticular masses of highly calcareous grey limestone. They thin westwards towards the shore-line of the Permian sea, which lay on the flanks of the Pennine ridge, then partly developed. The dolomitic limestones reach a thickness of over 100 feet, but sometimes the two types are interbedded in irregular bands. The calcareous rocks are locally, as in Thickley Quarry, composed of fossils in a well-preserved state, but inorganic limestones with an occasional specimen of *Productus horridus* occur in Raisby Hill Quarry, over 100 feet in thickness. The dolomitic beds of the Lower Limestone are chemical precipitates, and the calcareous beds represent conditions when the dolomitic precipitation was arrested. When followed northwards the Lower Limestones maintain their thickness as far as Sunderland, but they thin rapidly north and west of this area; in some sections it is, however, difficult to estimate their original thickness in these directions, as their upper beds have been disturbed and displaced along the major thrust-plane of this deformed area. They are, however, only about 30–40 feet thick in Frenchman's Bay, South Shields. Many of the geodes in this limestone now lined with calcite originally contained gypsum or anhydrite. Pockets containing these minerals have been proved in the borings in South Durham.

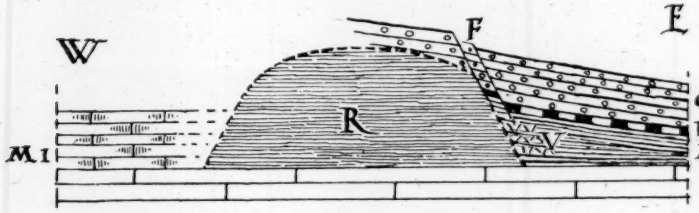

FIG. 1.—Diagrammatic section across the Bryozoa Reef to show the relations of the different divisions of the Magnesian Limestone to it. L, Lower Limestones. M_1, the western equivalents of the Reef, fossiliferous and unfossiliferous dolomites, granular dolomites, dolomitic oolite, and calcareous segregated rocks. R, the Bryozoa Reef. M_2, the eastern equivalents of the Reef, unfossiliferous dolomitic limestones, dolomitic oolite, calcareous segregated rocks, breccias, and pseudo-breccias. V, interbedded fossiliferous breccia—the Vor-reef. FL, the Flexible Limestone. C, the Concretionary Limestone. F, slickensided slip-planes. The length of the section is about two miles. The Bryozoa Reef is over 300 feet thick.

The Middle Limestone is of special interest as it exists under three distinct facies, and it was undoubtedly this fact that was one of the main difficulties in understanding the stratigraphy of the Magnesian Limestone. Running right through the division is the shell-bank of the Bryozoa Reef, usually called the Shell or Fossiliferous Limestone. It is generally about a mile across, and its total original thickness was over 300 feet. In the north it has been highly denuded, appearing as a series of rounded knolls, and is

distinctly traceable, running across country for a distance of 20 miles. It is dissected on Down Hill (Boldon Hills) and Claxheugh, near Sunderland, and to the south can be seen on the knolls and old quarries of Humbledon and Tunstall Hills, and in Fox Cover Quarry, Seaham Harbour. One of the best fossiliferous exposures occurs on the flanks of Beacon Hill, and it is exposed in old quarries at Easington and Horden, finally disappearing beneath the upper beds south of Castle Eden Dene. The sinking at Blackhall Colliery went right through this reef on its eastern flank, and Trechmann was able to study its fauna in an exceptional way. It was there 335 feet thick and was overlaid by Concretionary Limestone. In appearance and fauna it is similar to the Bryozoa Reef of the Zechstein of Thuringia.[1] Trechmann considers it to have been formed 10 or 12 miles from the western shore of the Permian sea.[2] It was originally a shell-bank—the Brachiopods and other forms sheltering among the Bryozoa—upon which was settling fine calcareous and dolomitic sediment. A great portion of the organically formed part of the limestone has undergone secondary dolomitization, either pene-contemporaneously with deposition or long after (both processes may have taken place), but some parts of the whole limestone are still calcareous. Near the reef in the off-shore equivalents there is an interbedded fossiliferous breccia, which was a Vor-reef formed of blocks broken off by the waves,[3] i.e. the Shell-Limestone Conglomerate of Howse exposed at Blackhall Rocks and in Hesleden Dene[4] (Photograph, Pl. XII, Fig. 2). On its western side current-bedded oolitic dolomites have been noticed in Silksworth Quarry, and some of the fossils in parts of the western equivalent of the reef appear to have been drifted from it. The fauna of the Permian sea of Durham received a sudden influx of species along the area now occupied by this shell-bank owing to the depth, temperature, and salinity of the water offering fairly congenial environment. About thirty invertebrate species lived in the Lower Limestone sea in small numbers, but in the reef a hundred flourished in the greatest profusion under, however, rather hard conditions, as they never reached any large size and gradually underwent extinction, only about sixteen species being left to continue a protracted existence during the deposition of the Upper Limestones, finally disappearing from the area when the Upper Red Beds with salt were being deposited. Brachiopods, polyzoa, corals, echinoids, and cephalopods all died out with the passing away of the reef conditions, none of these ever being found in the Upper Limestones. On its east or off-shore side the reef is replaced by yellow, bedded, unfossiliferous dolomites and segregated limestones, which

[1] E. Kuste, *Geologisches Wanderbuch für Ostthüringen und Westsachsen*, p. 141. J. G. Bornemann, "Von Eisenach nach Thal und Wuther": Jahrb. königl. preuss. geol. Landesanstalt, 1883. In 1913 Trechmann and I visited Thuringia in order to compare the Permian rocks of Durham and South Germany.

[2] Op. jam cit., vol. lxx, p. 259.

[3] A Vor-reef also occurs in Thuringia (E. Kuste, op. jam cit., p. 141).

[4] The coarse fragments in this bed are more or less rounded.

are so well exposed along the middle part of the Durham coast, and which often appear as breccias and pseudo-breccias, so that they have been called the Brecciated and Pseudo-Brecciated Limestones. On the west it is represented by a stratified series of scantily fossiliferous dolomites, granular dolomites, dolomitic oolites, and segregated calcareous rocks. This series only occurs fully developed under the drift in the south of the county; in the north it has been highly denuded. It can be studied in quarries near Silksworth and in Haswell Quarry. Occasional inroads of the fauna of the reef must have taken place into the lower beds of this facies when they were laid down, but some of the fossils in them were probably drifted in from the reef.

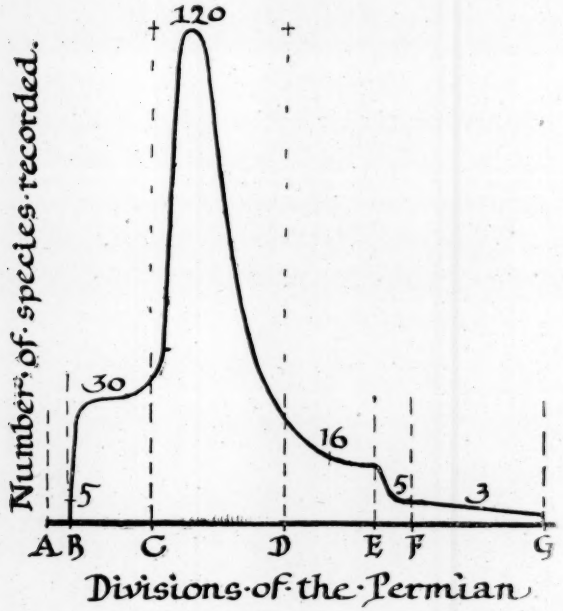

FIG. 2.—Curve showing the number of invertebrate species recorded in the different divisions of the Durham Permian. A curve showing the number of individuals would be of similar form with the height of the apex in the Bryozoa Reef enormously increased. A–B, the Yellow Sands. B, the Marl Slate. B–C, the Lower Limestones. C–D, the Bryozoa Reef. D–E, the Concretionary Limestone. E–F, the Roker and Hartlepool Oolite. F–G, the Upper Red Beds with salt.

The base of the Upper Limestone is marked by the Flexible Limestone, which I have traced all over the northern area, and the equivalent of which Trechmann has proved to occur in the south of the county. It marks a decrease in the depth of the Permian sea, recalling the Marl Slate in its laminations, occasional fish-remains, and high percentage of impurities, and seems to have been deposited under similar tranquil conditions in fairly deep off-shore waters.

FIG. 3.—Diagrammatic section across the Permian outcrop.

1. Coal-measures.
2. Yellow Sands.
3. Marl Slate.
4. Lower dolomitic and calcareous limestones.
5. Middle fossiliferous dolomite, the western equivalent of the Reef.
6. Bryozoa Reef.
7. Middle unfossiliferous dolomitic limestones, calcareous breccias, and segregated rocks, the eastern equivalent of the Reef.
8. The Flexible Limestone.
9. The Concretionary Limestone.
10. The Roker Oolite.

The length of the section is 6 miles. The height of Tunstall Hill above sea-level is 373 feet.

It probably, however, marks a decrease in the depth of the Permian sea on the east side of the reef, due to infilling by sediment and desiccation of the area. The Upper Limestones, which thicken eastwards, were thus laid down in shallower water and over a more restricted westward area than those below. They are thus retrogressive with respect to both the Lower and Middle Divisions. Their lower beds are equivalent to the higher parts of the reef. This can be proved by a study of the sections along the coast, and from the fact that in Blackhall Colliery sinking the Concretionary Limestone rested directly on the reef.[1] They lie in a broad syncline stretching from Marsden to the south of Sunderland, and are faulted-in at Seaham Harbour. Along the coast to the south one or two small synclines and faulted-in areas occur, and at Hartlepool they are well exposed. They consist of the highly altered concretionary limestones and of the Roker and Hartlepool oolites. The latter consist mainly of strata composed of minute hollow spheres, which were originally gypsiferous oolites.[2] These oolitic beds were probably not formed in water of any great depth, as King records ripple-marked limestones from their upper layers.

Above the Upper Limestones occur red marls, false-bedded sandstones, thin fossiliferous dolomitic limestones with salt, gypsum, and anhydrite. They occur to the west of the reef, but are of limited westward extension, which was pointed out by Lebour some years ago. They were also deposited to the east of their present Permian outcrop, as Trechmann has proved that similar beds were carried in by the Scandinavian ice-sheet and left in the glacial deposits near Castle Eden Dene.[3] They mark the drying up of the Permian sea, the final stages of which are represented by the deposits of the more soluble salts of calcium, magnesium, sodium, potassium of the Stassfurt area, which were probably deposited far to the west of their present proved position.

The Permian of Durham can be readily correlated with that of Thuringia.[4] The similarity of the Magnesian Limestone with the Zechstein proves the conditions of deposition were the same. In both cases they were laid down on the edge of the Permian sea, which must have stretched during a contracted period continuously between the two areas.

In the examination of any subsequent borings that may be made in South Durham or Yorkshire there are several points of interest

[1] Trechmann, Q.J.G.S., vol. lxix, p. 213, 1913.

[2] The hollow spherules in parts of this rock are very irregular, and have been referred to as being pseudo-oolitic and concretionary. The study of the oolites in other parts of the limestone and their microscopic structure prove that both the regular and irregular spherules are ooliths. They are inorganically-formed oolitic limestones formed by the deposition of dolomite round gypsum. When this substance dissolved out the dolomitic spherules was also partly removed. The ooliths with the gypsum still remaining in them from the cores of borings in South Durham show perfect oolitic structure.

[3] Q.J.G.S., vol. lxxi, p. 65.

[4] See table giving this correlation in my paper on Permian of North Durham, op. jam cit., p. 254.

that may be looked for, having a direct bearing on some of the questions discussed in this paper. (1) Are concretionary and segregated structures developed in the gypsiferous limestones? (2) Are the gypsiferous beds demagnesified? (3) Do gypsiferous oolites occur? (Gypsiferous oolite was proved in the Newcastle Chemical Works boring north of the Tees. The cores are now in Middlesbrough Museum.) (4) Can the reef be traced southwards? *Strophalosia* and *Dielasma* (both reef fossils) are recorded by Trechmann in the Warren Cement Works boring at Hartlepool from beneath the anhydrite. It should, however, be noticed that the Magnesian Limestone as exposed in Yorkshire and further south is a shallower-water deposit than that of Durham, so that the reef may never be reached by borings through strata to the south of this county.

The Thrusting in the Northern Area.

The northern area of the Durham Permian differs from the southern in a more extensive brecciation and disturbance of the strata. This results from the horizontal movements which can be proved to have acted in the northern area, but which appear to have had little effect in South Durham. Thus in the latter region unshattered segregated rocks occur, while in the northern area these rocks are usually brecciated. There is also much less general deformation and disturbance of strata in the south than in the north, and major and minor thrust-planes are not noticeable.[1] It is, however, probable that many of the fissures which form a feature of the middle and southern part of the Durham coast are tension phenomena produced at the end of the period of thrusting, when the pressures were relieved by the movement and the shattering of the strata.

The evidence proves that the horizontal movements, the effects of which are so clearly exposed in the Coal-measures along the south-east coast of Northumberland,[2] and the similar displacements which have produced such marked structural features in the Permian of South Northumberland and North Durham, were produced by the same cause. The effects of the thrusting can be clearly seen at many points along the coast from the north of Whitley to a few miles south of Sunderland, a total distance of about 15 miles, and inland on the Boldon Hills, at Claxheugh, and under the Sunderland district over an area of several square miles.[3] Stratigraphically the thrusting has affected several hundreds of feet of strata, and structures,

[1] It should, however, be noticed that the line of principal thrusting in the north (i.e. the junction between the Lower and Middle Limestones) is not exposed along the coast in the southern area.

[2] Lebour & Smythe, Q.J.G.S., vol. lxii, p. 530, 1906; Haselhurst, Proc. Univ. Durham Phil. Soc., vol. iv, pt. iii, p. 162, 1912; and Woolacott, "Geology of N.E. Durham and S.E. Northumberland": Proc. Geol. Assoc., May, 1912.

[3] The thrust at Marsden is described in Univ. Durham Phil. Soc. Mem., No. 1, 1909; at Claxheugh and on Down Hills in Trans. Nat. Hist. Soc. of Northumberland and Durham, N.S., vol. v, pt. i, p. 155, 1919; and a detailed account is given in my paper on the northern area of the Durham Permian, Proc. Univ. Durham Phil. Soc., vol. iv, pt. v, 1912.

displacements and disturbances caused by it can be seen in the Coal-measures, Yellow Sands, Marl Slate, Lower, Middle, and Upper Limestones. The remarkable feature about the thrusting is that it is directed to a more or less central area to the south of Marsden. The only exception recorded to this is the well-known case of thrust and unconformity in the Coal-measures at Whitley.[1] At this place Lebour and Smythe regard the thrusting as being directed towards the north, the massive upper sandstone having moved over the shales, etc., beneath it from south to north, but from my detailed study of the district I have for a long time regarded the Whitley section as a "lag fault", i.e. the under beds have moved south under a southerly directed pressure, leaving the massive sandstone behind. The result is the same, but this explanation of this section is necessitated, as the force acting along the Northumberland and Durham coast towards Marsden was a general southern one, and the movement of the strata was in that direction.[2] In my paper on the Permian of North Durham I give a map showing the direction of the thrusting movements that have been recorded in the Coal-measures and Permian of this area.

The Magnesian Limestone of Durham offers exposures of some of the structures which have been proved to exist in other regions of more intense thrusting, in so far as they could be impressed on these rocks by the magnitude of the pressures acting and on beds of such little variation in mineral composition. It is noticeable that in the strata affected by the thrusting flow-structures are not extensively developed.[3] It is only in portions of the softer rocks and along thrust-planes that incipient flow-structures occur, while brecciation, fracturing, etc., are developed on an extensive scale. These rocks are therefore of interest as giving an example of thrust movements affecting beds within the zone of fracture,[4] although locally parts of the rocks lay within their zone of flow. I have endeavoured to prove that the magnitude of the pressures acting in the Marsden area reached 300 tons per square foot.[5]

The marked effects produced by these horizontal movements in the Permian—movements which do not appear to have been greater than some 300 feet in displacement—are probably partly due to the cavernous, cellular, and porous nature of the rock caused by the removal of the sulphates which probably had been largely removed before the thrusting took place, although I think the rocks contained sulphate solutions at the time the pressures acted (Geol. Mag., October, 1919, Pt. I, p. 459).

[1] Q.J.G.S., vol. lxii, p. 530, 1906.

[2] Haselhurst gives evidence proving the pressure was from the north at Cullercoats, Univ. Durham Phil. Soc., vol. iv, pt. i, 1910–11, and I prove that the movement at Marsden was from the north-east.

[3] Flow-structures occur in the Coal-measures at Whitley, in the limestone above the thrust-plane at Hendon, in the Yellow Sands at Claxheugh, etc., but never on a large scale.

[4] Van Hise, "Principles of North American Pre-Cambrian Geology": Sixteenth Ann. Rep. U.S. Geol. Surv., p. 589, and Leith, *Structural Geology*, p. 3.

[5] Memoir on Marsden area, op. jam cit., p. 5.

The thrust-planes, folding, compression-structures, and other evidence of horizontal movement in these rocks are quite distinct, affect beds beneath which sulphates were laid down, and cannot have been directly caused by the removal of beds of gypsum or anhydrite, although a certain instability of the strata had most probably been produced by solution of such beds before the thrusting took place. The general effect of the thrusting has been to produce a decrease in the lateral extension of the Magnesian Limestone; the rocks—Coal-measures and Permian—which have not been fractured and brecciated have been bent into broad folds. The syncline of the Permian strata beneath Sunderland appears to be the direct result of these movements (see section, fig. 9, in my paper on North Durham, op. jam cit.).

The horizontality or general low hade of the thrust-planes, the damping down of the folds, the shear and flow structures prove that a considerable weight of rock lay above the thrust horizons at present exposed at the surface, when the deformation of the area took place.

It will probably be useful to geologists and geological students if I give a brief summary of the phenomena I have observed as being directly due to thrusting, with a short discussion of one or two points to which my attention has been drawn since I first wrote my account of this district.[1] They may be summed up as follows:—

1. Major and minor thrust-planes, with slickensided surfaces both above and beneath them. These planes occur on certain horizons, the most continuous being the top of the Lower Limestone. The top layers of this limestone have acted as a base on which the more cellular cavernous rocks of the Middle Limestone have been moved. The thrust-planes are not, however, confined to this horizon: sometimes minor fractures cut down through the Lower Limestone and affect the Marl Slate and Yellow Sands beneath, so that large masses of the Lower Limestone are displaced. These planes do not pass into the Yellow Sands, which as a rule appear to have given freely to the movement. In the railway cutting at Claxheugh highly disturbed beds of Lower Limestone are thrust over beds of the reef. Thrust-planes, however, occur at other horizons than at the junction between the Lower and Middle Limestones, the most marked being exposed in the cliff at Hendon at the southern limit of the broad syncline of the Concretionary Limestone beneath Sunderland. At this place the Middle Limestone is thrust over the Flexible and lower part of the Upper Limestone.[2]

2. Mylonized rock occurs along the thrust-planes. It is best developed at the Trow Rocks and in Frenchman's Bay. This peculiar layer of rock, an inch or two in thickness, which runs along the top of the disturbed beds or along the thrust-planes, is quite distinct in colour, appearance, and texture from the cementing material

[1] Fuller evidence is detailed in my memoir on the Marsden district, my general paper on the Permian of North Durham, and the paper in the Proc. Geol. Assoc. Photographs of many of the structures described will be found in these.

[2] See section, fig. 10, in Permian of North Durham.

of the breccias or from the calcite of the segregated rocks or from the powdery dolomite in other parts of the limestone.

3. The Magnesian Limestone has seldom been deformed without fracture, so that flow-structures[1] are not produced in it on a large scale, but at one or two places shear and flow structures and strain-slip planes are developed, and at Claxheugh the Yellow Sands were sheared up for several feet over a mass of breccia. At Hendon, along the thrust-plane, incipient flow-structures (a kind of megascopic pseudo-stromatic or phacoidal structure) has been developed in it.

4. At Claxheugh shear-planes on a large scale can be seen in the reef, the rock having given under the horizontal pressures into large lenticular masses.[2]

5. Folding due to thrusting is developed on a broad scale and on a very minute one. The broad syncline of the rigid Upper Magnesian Limestone beneath Sunderland, which extends from Marsden to Hendon, and is 6 miles across, was produced by these horizontally directed pressures,[3] and the dome in Cullercoats Bay is also due to them. Folding on a smaller scale is common at Marsden, and in one part of this section overfolding can be seen. At Claxheugh and in Cullercoats Bay overfolding on a very minute scale occurs in the softer beds of the Marl Slate.

6. Compression-jointing and fracture-cleavage are developed in the Magnesian Limestone at Marsden and slightly in other areas. At Marsden the distance between the parallel partings varies from a few inches to a minute fraction of an inch, the rock fracturing along these close parallel planes and the structure being seen for over a quarter of a mile along the coast (see Memoir on the Marsden area, section, fig. 8). In my paper on that section I have referred to this fissility of the rock as cleavage, a term which has been objected to by one geologist, who obviously had not seen the Marsden section, as inapplicable in connexion with these rocks. In that paper I defined the term clearly as "the flattening of the mineral particles by pressure, so that they have a parallel arrangement with their shorter axes in the direction of greatest stress".[4] As the word cleavage is now used in connexion with rocks in two senses—"fracture-cleavage" and "flow-cleavage"[5]—I gave this definition in order to show clearly that I was using the term simply to denote a compression structure, i.e. fracture-cleavage, close-joint-cleavage, etc., and not flow-cleavage. I showed that this compression-jointing (when coarse it may be called this) or fracture-cleavage was developed at Marsden at right angles to the pressure after the folding, but before the brecciation of the rock took place.

7. Crush breccias, where beds have been thrust against a horst-like

[1] i.e. permanent change of form without conspicuous fracture.

[2] See section of Claxheugh in Trans. Nat. Hist. Soc., op. jam cit., 1919.

[3] A general section of the coast is given in my paper on North Durham, fig. 9.

[4] Memoir on Marsden, p. 10. Sorby showed that this structure had been impressed on Devonian Limestones by pressure "On Slaty Cleavage as exhibited in the Devonian Limestone of Devonshire": Phil. Mag., vol. xi, p. 20; vol. xii, p. 127, 1856.

[5] Leith, *Structural Geology*, p. 10.

mass, and shattered when the pressures developed reached the compressive strength of the rock, e.g. Marsden.[1]

8. Thrust breccias, where beds have been horizontally moved along a thrust-plane and shattered during the movement. These rocks in some cases appear to have been cellular, segregated rocks before the thrusting took place, and so were easily shattered. Such beds are seen in Frenchman's Bay, on Boldon Hills, at Claxheugh, etc.

9. Intruded breccias. Breccias which have been forced up into beds above (Jean Jiveson's rock, Ryhope),[2] or down into beds beneath (seen in a section near the Church, West Boldon).

10. Missing strata, often of considerable thickness, e.g. at Claxheugh, Down Hill.

11. Highly disturbed masses of limestone which have been moved horizontally out of their original position, e.g. near Hylton Castle, Claxheugh, Frenchman's Bay.

12. At Marsden and Hendon, on the edges of the syncline beneath Sunderland, the limestone has been fractured into large irregular blocks without appreciable displacement. These rocks I have called the "block fractured".

13. Slickensided surfaces are common and are usually found in all exposures where thrust movements have taken place. Minute slickensided surfaces have been observed in the Marl Slate at Cullercoats and Claxheugh, while a horizontal slickensided surface of some extent is exposed beneath the base of the reef at Claxheugh. The breccia of Jean Jiveson's rock is cut by several vertical slickensided planes (Photograph, Pl. XII, Fig. 1).

14. Many of the fissures, breccia-fissures, and (probably also the breccia-gashes) where formed by tension when the pressure was relieved by movement and shattering of the strata.

The Breccias.

The brecciation of the strata is one of the most pronounced features of the Durham Magnesian Limestone. In the course of this paper four or five types have been mentioned, and several causes have been referred to as having produced these autoclastic and clastic rocks. It has also been asserted that sometimes two causes may have contributed to the production of some of these shattered beds.

In a rock which over a large area has been deformed by thrusting within the zone of fracture by forces of some magnitude, and which has had removed from it beds generally more or less lenticular and probably of considerable extent, and sometimes also of great thickness (probably reaching two or three hundred feet), veins, and intercalations of one of its original constituents, it is evident that such shattering of the strata must have been brought about by these two causes, and that it may sometimes be impossible to decide how far only one of these was operative in producing particular breccias. The cause of the brecciation is further complicated by the fact that segregation and solution changes have also contributed in bringing

[1] Memoir on Marsden, p. 5 and photograph.

[2] I regard the breccia of Jean Jiveson's rock as being directly connected with the thrust-plane at Hendon about half a mile to the north.

about an unstable condition of the strata, and that contemporaneous brecciation also occurs.

The breccias may be classified as follows:—

1. *Contemporaneous Breccias.*—In the Lower Limestone as recorded by Trechmann and myself, incipient brecciation occurs.[1] The rock is minutely fractured without any appreciable displacement, a feature most probably due to shrinkage of the rock on drying.

2. *Clastic Breccia.*—The interbedded fossiliferous breccia-conglomerate of Blackhall Rocks and Hesleden Dene, i.e. the Vor-reef, is an example of this type (Photograph, Pl. XII, Fig. 2).

3. *Pseudo-breccias.*—(*a*) Some dolomitic rocks in the Magnesian Limestone assume a brecciated appearance due to the patchy development of fine yellow dolomite among the crystalline calcite.[2] These are true pseudo-breccias, and have been brought about by segregation processes.

(*b*) Some of the rocks which were called pseudo-breccias by King[3] are segregated rocks which have broken up, (1) by mere collapse due to their cellular nature when the sulphates were removed and the segregation processes complete, (2) by the letting down of these beds due to the removal of the sulphates,[4] and (3) by shattering produced by movement at the time of thrusting.[5]

4. *Autoclastic Breccias.*—Breccias directly due to thrusting include (*a*) crush breccias, (*b*) thrust breccias, (*c*) brecciated folds, and (*d*) rocks which have been broken up after having had compression-jointing impressed on them.[6]

5. *Solution Breccias.*—Breccias due to the collapse of the strata caused by the removal of beds of anhydrite or gypsum.[7]

6. The gypsiferous breccias occurring in the Warren Cement Works boring are probably due to the breaking up of the rock caused by the expansion produced by the alteration of anhydrite into gypsum.

7. *Vein-dolomitized Breccias.*—The coarse dolomitic breccias exposed in the bluestones of Raisby Hill Quarry (calcite 98–9 per cent) are due to the alteration of these rocks by magnesium, copper, and manganese solutions.

8. Breccias filling breccia-fissures and breccia-gashes. These are well exposed in the Marsden district. The vertical fissures filled with coarse breccia are sometimes 40 and 50 feet wide, and large blocks have fallen considerable distances into them.

[1] Woolacott, GEOL. MAG., March, 1919, pp. 164–5.

[2] Similar rocks have been noticed by L. M. Parsons in Carboniferous dolomites. "Dolomitization and Leicestershire Dolomites": GEOL. MAG., 1918, p. 250.

[3] King, Monograph of Permian Fossils, Pal. Soc., 1849.

[4] Broken up segregated rocks of the first two types occur on the eastern flanks of the reef. Vertical slickensided surfaces produced by the slipping down of these beds have been noticed by Trechmann.

[5] Shattered rocks of this type occur in the Marsden area and in the Claxheugh and Boldon Hills districts.

[6] These are all best developed in the Marsden district.

[7] The very coarse breccias south of Seaham Harbour where brecciation associated with faulting is extensively developed are probably the best example of this type.

The most widespread breccias are the autoclastic breccias in the north of the county, the broken-up beds due to the removal of the sulphates, and the pseudo-breccias. It is a very noticeable feature of many of the breccias that they are more calcareous than the dolomitic limestones from which they were formed.

Summary.

The main conclusions that have been arrived at by recent work on the Magnesian Limestone of Durham are:—

1. That the series of bedded dolomites, dolomitic limestones, and calcareous beds which form the main mass of these rocks are the result of chemical precipitation, and that they originally contained thick and thin beds, veins, pockets, and impregnations of anhydrite and gypsum.

2. That the main mass of the dolomite and dolomitic limestones was either precipitated as a double salt or formed by the combination of the associated carbonates after precipitation, and that it is possible that examples of both of these methods of formation occur.

3. That the Bryozoa Reef and small beds and lenticles in the Lower and Upper Limestones were organically formed, and consist of remains of organisms on which dolomitic or calcareous sediment settled.

4. That calcium sulphate appears to have been a subsidiary product of the deposition of dolomite and dolomitic limestone.

5. That while the main mass of the dolomite was chemically precipitated some parts, e.g. parts of the reef, etc., may have been dolomitized pene-contemporaneously with deposition and others long after.

6. That the Middle Magnesian Limestone exists under three distinct facies, consisting of a Bryozoa Reef and its bedded in-shore and off-shore equivalents.

7. That (except in the case of parts of the reef, etc.) the cellular structures in the Magnesian Limestone were not produced by subsequent dolomitization.

8. That parts of the Magnesian Limestone are more calcareous than they were originally; the non-cellular type of these "demagnesified rocks" occurs principally within the zone of thrusting, while the cellular types are the highly altered concretionary, segregated, and other rocks.

9. That the chief non-cellular "demagnesified rocks" and breccias were probably produced by the action of solutions of calcium sulphate on the dolomite, the magnesium being dissolved out as a sulphate and metasomatically replaced by calcium.

10. That the concretionary rocks may have been produced in solutions of calcium sulphate containing colloidal organic matter, the more definite spherical types being formed in regions where the organic matter was concentrated.

11. That the calcareous segregated rocks may have been formed in sulphate solutions free from organic matter.

12. That solution of part of the magnesium-content of the concretionary and segregated rocks has probably gone on, and that

(whether it has or not) the dolomitic powder, which has been or is being carried away mechanically, was set free as a result of the concretionary and segregated processes, and its removal has nothing to do with the cause of these structures.

13. That the dolomitic and gypsiferous dolomitic oolites were produced by deposition of material round crystalline grains or nuclei either as they fell through the water or lay on the bottom of the sea.

14. That the northern part of the Durham Permian (and the Coal-measures and Permian of South-East Northumberland) form a region of thrusting in which many of the phenomena of areas of more intense thrusting are exposed, and that these rocks afford an example of deformation produced within the zone of fracture.

15. That the breccias and pseudo-breccias which form such a marked feature of these rocks were produced in several distinct ways, each exposure of them requiring to be separately examined before their mode of formation can be elucidated.

Addendum.—I desire to thank Dr. Trechmann and Dr. Smythe for reading the first draft of this paper through and adding one or two notes which aided me in preparing the final paper. I do not, however, wish to make either of them responsible for any of the views expressed in this paper, except those of Dr. Trechmann which are directly quoted and referred to in the text.

EXPLANATION OF PLATE XII.

Fig. 1.—The Shell-Limestone conglomerate at Blackhall Rocks. Portion of Vor-reef of the Bryozoa Reef.

Fig. 2.—Jean Jiveson's Rock. Coast one mile south of Sunderland. This is a mass of compact calcareous breccia cut by several slickensided planes, one of which can be seen on the left. The rock was originally a dolomitic limestone, and has been altered by solution.

II.—Geology of Kinkell Ness, Fifeshire.

By David Balsillie, F.G.S., University, Edinburgh.

(PLATE XIII.)

THE largest, best exposed, and most interesting volcanic vent along the northern shores of Fife is that which has been laid bare at the headland of Kinkell Ness, and a portion of whose enclosed material has been sculptured into the picturesque shore stack known as the Rock and Spindle. ("These two words," as Sir A. Geikie points out, "are generally misunderstood. 'Rock' is the Scots word for a distaff; and 'Spindle', as here used, has reference to the stellate mass of basalt resembling a spinning wheel.") Reason for this appropriate designation will be readily gathered from the accompanying photograph (Plate XIII).

There would appear little doubt that this curious volcanic relic, whose characters are sufficiently striking to arrest the attention of the non-geological observer, was the cause of speculation and controversy in the early days of geological science—certainly before the luminous teachings of Hutton and Playfair had attained a definite ascendency over the enunciations of the Neptunists. Thus in the year 1813 the Rev. John Fleming, minister of Flisk parish on

Photo. D. W.

FIG. 1.

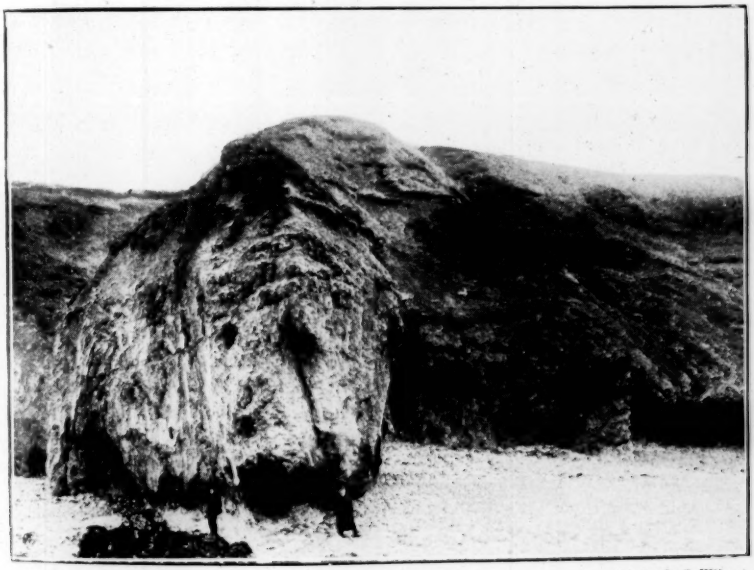

Photo. O. C. Wilmot.

FIG. 2.

the southern shores of the Firth of Tay, in a contribution to the Memoirs of the Wernerian Society,[1] gave descriptions of the remarkable "trap tuffs" in the neighbourhood of St. Andrews and relegated them in characteristic Wernerian terminology to the newest Floetz-trap formation. Referring to the agglomerate and "spherical concretion" of basalt at the Rock and Spindle he maintained that the two rocks could be seen to pass insensibly into one another, and accounted for the whole in the light of his adopted hypothesis by inferring that it was "partly a mechanical and partly a chemical deposit".

From the time of Fleming for over the next sixty years little appears to have been accomplished towards any correct elucidation of the natural history of the tuffs in East Fife. They were mapped by the officers of the Geological Survey as masses interbedded with the rocks among which they occur, and this idea found expression on the 1 inch map, sheet 41, published in 1861. Eighteen years later, however, a change in concept was brought about by the appearance, in 1879, of Sir A. Geikie's well-known paper "On the Carboniferous Volcanic Rocks in the Basin of the Firth of Forth; their Structure in the Field and under the Microscope".[2] In that paper the author, turning to account, as he himself admits, valuable experience gained on the East Lothian coast and in Ayrshire, clearly recognized the intrusive nature of many of the tuffs, and asserted that these represented the sites of former active volcanoes which must have come into eruption long after the deposition of the Carboniferous strata which they penetrate. More recently the same writer has again given an account of them in his *Ancient Volcanoes of Great Britain*, also, with amplification, in the Geological Survey memoir,[3] published in 1902.

The general outline of the Rock and Spindle vent, as may quickly be ascertained, is altogether irregular and suggests a shifting of the focus of the volcanic forces by which it was produced. Thus two nearly detached areas of agglomerate on the north may mark independent orifices. Only on the eastern and northern sides are the margins of the opening available for examination, they being concealed elsewhere beneath the grassy cliff-line and by the sand and shingle above high-water mark.

The rocks surrounding the neck, which consist in large part of thinly-bedded sandstones with thick intervening shale bands, one of which is crowded with *Naiadites*, lie not far above the Encrinite-bed, which is an easily recognizable stratum in the Calciferous Sandstone Series of East Fife, and which crops out on the beach about 300 yards to the east of Kinkell Ness. On the Anstruther–St. Monans foreshore, which is taken as the typical area for the study of the Calciferous Sandstones in East Fife, Mr. Kirkby estimated the depth of the Encrinite-bed beneath the base of the Carboniferous Limestone Series as being about 2,280 feet.[4] On the north coast of the county,

[1] Vol. ii, 1813.
[2] Trans. Roy. Soc. Edin., vol. xxii, 1879.
[3] *The Geology of Eastern Fife*, Mem. Geol. Survey, 1902.
[4] Q.J.G.S., vol. xxxvi, 1880.

however, the intervening thickness of sediments is certainly a good deal less than this.

The strata that form the northern walls of the vent have, as has been pointed out by Sir A. Geikie,[1] been "violently disrupted". Enormous masses and blocks of sandstone and sandy shale are here to be seen standing at all angles in a matrix made up in the main of non-volcanic detritus, though containing abundant pieces of white trap, which has inserted itself into cracks and fissures in the sedimentary fragments, behaving, in fact, as if it were an intruded igneous rock. These curious fragmental rocks, exhibiting always the same general characters, are to be seen over and over again along the Fife shores. They were probably at one time liquid volcanic muds, their present mode of occurrence being merely an expression of a former high degree of mobility.

To the student of volcanic geology these peripheral non-volcanic areas in the larger vents afford considerable interest. It is obvious they must have lain permanently clear of the actively erupting channel; otherwise they could not have been preserved. There is thus the implication that the actual shape of the volcanic chimney towards the earth's surface is that of an expanding cone; in other words, that in vertical section it would resemble in some degree that of a filter-funnel held the proper way up. There is, however, the alternative explanation, and one that seems very likely, that sometimes they may not have been formed early in the history of the vent at all but rather towards its close, when the upstanding sedimentary walls were undergoing disintegration and were sending down their debris into the ash around the margins of the neck.

The major portion of the opening is occupied by a dark tuff made up of lapilli and nut-like fragments of basic lava and fine ash. In this ground-mass, which is sometimes almost black from the amount of intermingled coal-dust, are distributed numerous blocks of basalt and of various sedimentary rocks. Conspicuous among the latter are rounded or subangular fragments of a grey limestone weathering white. A curious interest attaches to these. Some years ago it was found by careful examination that they contain the remains of forms of marine life such as *Lithostrotion junceum* and *L. irregulare*, as well as other corals, brachiopods, and lamellibranchs, the species being common forms in the Carboniferous Limestone Series.[2] The significance of this will be appreciated when it is recalled that the strata now surrounding the opening belong to an inferior group of sediments, namely, the Calciferous Sandstone Series. The interpretation to be placed on the observed facts would appear to be that some, at least, of the basement beds of the Carboniferous Limestone Series formerly overspread this portion of the county and were actually penetrated by the vent. The disrupted fragments became enclosed in the agglomerate which subsequently subsided within the orifice, while the overlying and surrounding sedimentary rocks have been entirely swept away. Support for this opinion is obtained from the fact that wedged in

[1] *The Geology of Eastern Fife*, p. 208.
[2] Geol. Mag., 1911.

almost vertically in the seaward extension of the agglomerate are several large masses of coral-bearing limestone whose parent stratum must have measured at least 10 feet in thickness. These almost certainly belong to the base of the Carboniferous Limestone Series.

Throughout the greater part of the vent the infilling materials show an obvious assortment. Standing about 10 yards to the east of the middle of the three conspicuously protruding masses on the beach a concentric disposition of the outcrops of the tuff layers will be visible (Plate XIII). The concentricity is, however, not perfect, the imperfection occurring towards the north, where the outcrops, instead of swinging round to complete their respective circles, are prolonged in that direction and become apparently considerably displaced. Additional reference to this fact will be made further on.

The tuff layers are often irregular and show false bedding and occasional unconformity, the latter probably pointing to prolonged intervals of quiescence in the history of the vent. Layers of fine ash alternate with zones of coarser material and frequently preserve by their indentation under a large block or bomb an interesting record of some old aerial journey that was terminated by descent into the soft accumulations along the inner slopes of the cone.

The materials of the vent have apparently suffered a good deal of faulting and displacement. Sometimes also they are traversed by veins of dark-bedded ash that transgress the stratification proper of the neck. Of these the writer has arrived at no completely satisfactory explanation. At one part there is a coarse grit containing abundant blue opaline quartzes, a number of lava fragments, and at least one large block of white limestone. The mode of occurrence of this mass would suggest that it was laid down in some old crater pool during a period of quiescence, and that the materials from which it was built up were derived from some coarse, easily disintegrable grit, while down the adjacent ash-slopes there rolled into the water an occasional lava fragment or other block of non-volcanic origin.

While, as Sir A. Geikie mentions,[1] "there is no evidence that lava was ever discharged from this vent, the ascent of molten rock in the chimney of the volcano is impressively shown by the numerous intrusions of olivine basalt and limburgite that intersect the tuff." These, as further pointed out by the same authority, are not all of one date, but belong at least to two and perhaps three different epochs of injection. The older basalt is generally a dark-green decomposing felspathic olivine-bearing rock that in the majority of cases has involved so many included fragments in its substance that its simulation of an agglomerate is complete. The only possible mode of origin of such curious and thoroughly deceptive material would appear to be that the basalt had risen in the chimney in a highly liquid condition, and that having caught up a large amount of extraneous material early in its ascent had inserted itself among the ash of the higher parts of the neck, not as a homogeneous medium but rather as a species of mobile "concrete" (if it is permissible to apply such a term to a natural product). On cooling

[1] *The Geology of Eastern Fife*, p. 210.

it will be obvious that any portion of such a mass which by chance had remained clear of xenolithic ingredients would tend to display its characteristic symmetrical jointing, the jointed igneous rock passing insensibly, as observed by Fleming, into the "agglomerate".

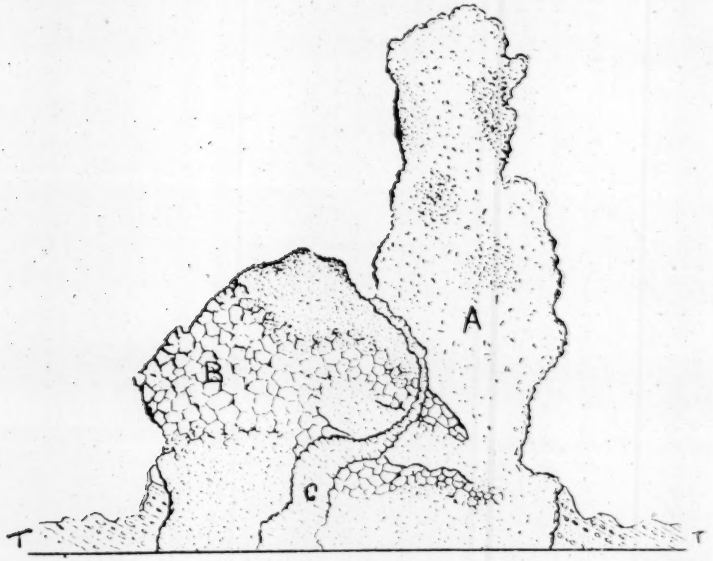

FIG. 1.—Diagram to illustrate structure of Rock and Spindle shore stack as seen from the east side. TT, older bedded tuffs of the vent forming the beach platform. A, intrusive basalt with included fragments. B, a portion of the basalt—forming the spindle—which, remaining clear of fragments, has jointed symmetrically. C, dyke cutting both A and B. Further references in text.

In light of what has just been said, Fig. 1 is given as representing the structure of the Rock and Spindle shore stack. The appearance of B as intrusive into A may be due merely to movement of one part of the mass against the other. The opinion is, of course, perfectly admissible that B has been introduced, while A was still uncooled and had become welded on to it. There can be no question as to the posteriority of the dyke C which stretches far out into the eastern wall of the opening, and indeed cuts another neck. It appears to belong to the final chapter in the volcanic history at this part.

The geologist walking over the beach platform of ash at Kinkell will have no difficulty in detecting by their prominence—contingent upon their superior durability—other masses of similar kind to the Rock and Spindle itself. Among these may be mentioned specially the first large stack that meets the eye on coming round Kinkell Ness from St. Andrews. This, at a first inspection, appears to be an exceedingly coarse agglomerate that encloses fragments of the older dark tuff. Careful examination, however, will again, it is believed,

make clear that this is not really a fragmental rock in the ordinary sense but is intrusive in nature, some of the marginal parts of the intrusion being unmistakably basaltic both mega- and microscopically. It can readily be imagined that if any mass were to originate in the manner described and that before cooling all excess of liquid rock were to be drained away, how thoroughly deceptive in appearance it might ultimately become. Many of the smaller necks in East Fife are, one is inclined to think, filled with material of this kind and ought not to be regarded as being subaerial pyroclastic accumulations, as ordinarily understood, at all. The extreme alteration of the sedimentary fragments in such instances (as also in the corresponding parts of the Rock and Spindle) would then find satisfactory explanation, for it is difficult to understand how this could have resulted from any mere transient experience of high temperature.

Petrographically the basalt of the Spindle is interesting. It is an exceedingly black compact rock that, like the basalts of St. Monans and Elie, encloses numerous crystals of glassy felspar and dark hornblende. Being desirous of ascertaining whether it further resembled the similar rocks on the south coast of the country in containing any felspathoid the writer had several sections of it cut and submitted these to Dr. Flett. He reports, as the result of his examination, that though the olivines are too greatly altered for one to expect nepheline to be now recognizable, nevertheless he believes that in one of the slides he can identify this mineral. He remarks on its strong resemblance to the Elie rocks and further compares it with the crystalline rock that occurs in the neck on the foreshore at John o' Groats.[1] Dr. Robert Campbell, who has also examined the slices, concurs in this opinion, and says that whether nepheline is now recognizable or not is a matter of small importance, as the general resemblance of the Spindle basalt to the Chapel Ness and other neck basalts of Elie is so remarkably close as to place their related origin beyond question.

Another curious and perhaps somewhat unusual fact is that the basalt of the Spindle contains numerous fish-teeth, enclosed apparently directly by the igneous rock; at all events no example has ever been found with attached sedimentary matrix. They appear to have been caught up directly by the basalt and ought thus to afford, if they could be specifically identified, important evidence as to the geological age of the vent. In the hope, therefore, that at last it might be possible to settle definitely a much controverted question a number of these remains were collected and handed to Dr. Flett, who forwarded them to Dr. Smith Woodward. This distinguished palæontologist thought at first that he could identify one of the specimens as belonging to *Rhizodus*, but further reported: "I have now an excellent micro-section of the tooth (in basalt) which I supposed to be Rhizodont, but, although I think there is no doubt about its being a tooth, all the structure has been destroyed and the specimen shows only the pulp cavity and cracks. Unless,

[1] *Geology of Caithness* (Mem. Geol. Surv. Scot.).

therefore, specimens can be got with the outer contour preserved it will not be possible for me to name or determine the age of these teeth." Unfortunately I have not so far had opportunity of searching for better specimens.

In further reference to the age of the Rock and Spindle vent it may at first serve some useful purpose to regard it merely as one of a great connected series and discuss briefly the general question of the antiquity of the necks in East Fife.

As has been pointed out by Sir Archibald Geikie,[1] not only are the necks later than the strata through which they rise, they are later also than the development of the tectonic features, i.e. the plication and faulting of the area. One particularly interesting example confirming this which does not formerly appear to have been brought to notice occurs on the beach just where the Encrinite-bed comes to the surface east from Kinkell Ness. Here it can be seen that a vent has risen along the line of a fault but has not had its enclosed materials shifted by the fracture, although the Encrinite-bed and its overlying *Naiadites* limestone are cut off and have been displaced considerably to the north-west. Sir A. Geikie believes, and, one is inclined to think, rightly believes, that if we regard the vents as belonging to one period, and that is an important point, then not only are they later, but a good deal later, than the youngest Carboniferous strata of the district. The next matter, therefore, to settle is, how long posterior to the youngest Coal-measures are they?

Further, briefly summarizing Sir A. Geikie's opinions on the matter it may be stated that he correlated the vents in East Fife with certain vents in Ayrshire which are believed to be of Permian age. He argued that the now visible parts of the necks, consisting in many cases of bedded ashes and tuffs, could not be far removed from the actual crater bases of the old volcanoes, and that therefore there could not have taken place since Permian times such an amount of erosion as one might reasonably expect. He concluded that the whole district must have been buried under younger—possibly Mesozoic—deposits, and in this way preserved. The removal of these younger sediments had restored the topography approximately to what it was in the days of active vulcanicity. Memorials of the vanished formation he thought he could detect in the staining and reddling of the rocks in the eastern portion of the county, and in support of that opinion cited similar evidence of staining in Dumfriesshire, where it could be demonstrated that Triassic sandstones and marls had been stripped off from an area over a hundred square miles in extent.

To Sir Archibald Geikie's long and masterly discussion the writer can presume to add but little. It does not seem easy to admit that all the vents in East Fife can belong exactly to one period, even although petrographically their materials present such uniformity of character. Thus, for instance, a series of boreholes on the outer flanks of Largo Law has afforded clear indication that there was contemporaneous volcanic activity in that area in Carboniferous

[1] *The Geology of Eastern Fife*, p. 279.

Limestone times and that possibly this vent ought to be relegated to that period. Notwithstanding the significance which must be attached to this kind of evidence, however, it seems exceedingly hard to question the validity of the contention that, in cases where the stratified rocks have been folded and faulted anterior to their disruption by active volcanic forces, deposition must have been followed by diastropic change more closely than by igneous action. Now, as is well known, the period of comparatively stable equilibrium that obtained over Western Europe during the Carboniferous Period was brought to an end at the close of Westphalian times by a powerful series of earth movements, the direction of maximum stress over the Northern British area being approximately from east to west. It would appear to have been at this time that the folding and thrusting of the Scottish Carboniferous rocks was inaugurated and carried to completion. We may be sure that such a major readjustment of internal forces as then took place would not be unaccompanied, as integral in the sequence of events, by its concomitant or subsequent cycle of igneous activity, and it is to this period of terrestrial instability, as it affected our own country in the northern part of its extent, that probably should be relegated the necks of East Fife. Such a relegation—which is really only bringing the vents a little nearer the Carboniferous Period than has been done by Sir Archibald Geikie—in close association with a great series of crustal disturbances would explain how it is that we find among the igneous phenomena of the Carboniferous rocks in Central Scotland so much apparently conflicting evidence, e.g. vents later than dolerite sills, east and west dolerite dykes later than vents, dykes rising along faults or being shifted by them, etc.

Referring particularly to the Rock and Spindle, there is no clear evidence that this vent is necessarily later than the tilting of the strata through which it rises. If the fossil fish-teeth which, as mentioned, have been found to occur in the Spindle should prove not to have been derived, but have been caught up directly by the ascending basalt, from the floor of some old crater pool to which the sea had access, they may yet be expected to afford an important clue as to the age of the neck. There is one other matter also in the case of this vent which may possibly suggest a somewhat earlier age. Reference has been made to the concentric bedding of the ash and to the fact that the outcrops of successive layers did not form perfect circles. It will be clear that if the chimney were rising vertically through already tilted strata the circularity of the outcrops ought to be perfect, they being the traces of a series of conical shells with vertical axes upon a horizontal plane. On the other hand, should the chimney be tilted along with its surrounding sediments, then one might expect that the outcrops should be elliptical, the degree of ellipticity being an expression of the inclination of the pipe to the vertical. It is perhaps some explanation of this kind that accounts for the irregularity discernible in the ash at Kinkell, though it may readily be argued that it is altogether unwise to reason in such fashion about the deposits of an old volcano that obviously have suffered considerable disturbance subsequent to their accumulation.

Probably an acquaintance with modern active volcanoes would lead one to attribute the phenomenon solely to a breaching of the cone on its northern side by later explosions. Such speculation, however, does not appear quite without interest, especially where other evidences are so little available.

For the photographs which illustrate this paper it is a pleasure to express indebtedness to Mr. John C. Caldwell, M.A., of the Madras College, St. Andrews.

EXPLANATION OF PLATE XIII.

FIG. 1.—Rock and Spindle shore stack, 2 miles east from St. Andrews. The fossil fish-teeth reported on by Dr. Smith Woodward were collected from the centre of the Spindle.

,, 2.—Concentric arrangement of ash layers, Rock and Spindle. In the distance may be seen the stratified rocks beyond the eastern margin of the vent.

III.—CHROMITE IN BEER STONE.

By G. M. DAVIES, M.Sc., F.G.S.

THE Beer Stone is a gritty limestone, made up largely of shell fragments with some foraminifera, quartz grains, and soft chalky material, occurring in the *Rhynchonella Cuvieri* zone of the Middle Chalk near Beer Head in the south-east of Devon. It has long been worked for building purposes in underground galleries about one mile west of the village of Beer, and has been described by W. Hill and W. F. Hume in the Geological Survey memoir on the Lower and Middle Chalk.[1] Dr. Hume records the following minerals as present in the insoluble residue of the stone: quartz, muscovite, glauconite, chalcedony, pyrites, tourmaline, rutile, andalusite, and possibly anatase.[2] A. J. Jukes-Browne[3] says the residue "contains a variety of minerals which have clearly been derived from land consisting of granite and Palæozoic rocks such as occur in South Devon and Cornwall".

Samples collected by me last year in the underground workings have yielded additional evidence which is of some interest.

A sample weighing 157 grammes was treated with dilute hydrochloric acid and yielded 3·1 per cent muddy residue and 0·32 per cent sand. The latter consists chiefly of quartz, up to 2·1 mm. diameter, the larger grains being well rounded. There is also a fair amount of felspar, mainly orthoclase, and of muscovite and glauconite, as well as a little flint.

The sandy material was treated with bromoform, and the heavy residue was found to amount to 0·012 per cent of the stone. Coarse red and black grains are conspicuous in it. The former consist of limonitic matter, and the latter were tested in borax beads on the supposition that they might contain manganese. The beads, however, showed the fine green colour, somewhat yellowish in the oxidizing flame, characteristic of chromium. On crushing the

[1] *Cretaceous Rocks of Britain*, vol. ii, 1903.
[2] Ibid., pp. 509, 513.
[3] Ibid., p. 545.

FIG. 1.

FIG. 2.

black grains and examining them under the microscope the fragments exhibit the deep brown colour in transmitted light and the isotropic character of chromite. In several instances a green serpentine is associated with the chromite. The other heavy minerals present are tourmaline, staurolite, biotite, zircon, rutile, and andalusite, none of which call for special comment.

A second sample gave 0·28 per cent sandy residue, but no chromite was seen in it. A thin section of the stone showed as many as seven fairly large quartz grains in an area of about half a square inch.

Detrital chromite does not seem to have been recorded in any Cretaceous or older deposits in England. From this fact, as well as from the coarseness of the grains and the patchy nature of the occurrence, we may conclude that the chromite was derived directly from some area of ultra-basic rocks, possibly the Lizard, possibly an area now submerged beneath the English Channel; and the occurrence is of interest as showing that serpentines as well as granites were being eroded in Turonian times.

IV.—On the Occurrence of *Productus humerosus* (=*sublævis*) in Dove Dale; and its Value as a Zone-fossil.

By J. Wilfrid Jackson, F.G.S., Manchester Museum.

During a recent examination of the Carboniferous Limestone in the Dove Dale district I have met with an abundance of *Productus humerosus*.[1] This species is a common fossil in the cliffs extending for a distance of quite 2 miles from the top end of Nabs Dale to beyond Tissington Spires. It is most prolific at and near Reynard's Cave, where the shells occur in clusters, often cupped into each other.

The beds containing this fossil are apparently not far below the top of the limestone, probably not more than some 500 feet.

The limestone is dark-grey in colour, with very obscure bedding. It breaks up irregularly into angular fragments, and contains some crinoid debris in places. Here and there occurs an organism of the nature of a Stromatoporoid, which invests the various fossils. There is an absence of chert, the limestone being very pure.

In addition to *P. humerosus* the beds contain *Amplexus coralloides* (very common), and several interesting Brachiopods, Gastropods, and Lamellibranchs; also Trilobites and Fenestellids, the fossils occurring in nests in certain places.

The specimens of *P. humerosus* include several varietal forms, which may or may not deserve distinctive names. Pending an exhaustive study of the material from Dove Dale and Caldon Low I here use the specific name *humerosus* to cover all such variations. Four such forms may be distinguished, but these are linked together by intermediates:—

1. *P.* aff. *sublævis*, de Kon., almost smooth, narrow and highly convex, with no trace of median sinus; flattened down median area from the beak to the anterior margin.

[1] First recorded in Geol. Mag., July, 1919, p. 335.

2. *P. sublævis*, de Kon., highly convex, characterized by a very definite median sinus (without a central spinous ridge) and concentric ribbing on umbonal region.

3. *P.* aff. *christiani*, de Kon., narrow and broad forms, with indistinct central spinous ridge (represented in some by a row of well-spaced spine-bases, which very late on are situated on a ridge); indistinct, or no, median sinus; concentric ribbing as in last.

4. *P. christiani*, de Kon., large, broad forms, with distinct central spinous ridge commencing near beak, sometimes in a sinus; concentric ribbing as last.

The same four variations are present at Caldon Low, but of the specimens I have examined the majority appertain to var. (2); whereas at Dove Dale the dominant form is (3).

From what I have seen of the Breedon (Leicester) specimens they seem referable to (3) or (4); but being mainly casts, it is difficult to be sure. Some certainly show evidence of a median ridge.

Examples of the variant (1) (which I here term *P.* aff. *sublævis*), are figured by Delépine ("Calc. Carb. Belg.," Mém. Facult. Cath. Lille, 1911, pl. xiv, figs. 3, 3*a*), and by Vaughan (Q.J.G.S., vol. lxxi, pl. vii, fig. 8, 1915).

Among the other Dove Dale Brachiopods the most interesting are: a giant papilionaceous *Chonetes* (190 + mm. along the hinge-line); a remarkable variety of *Productus mesolobus* (quite unlike the form from the "Brachiopod-beds"); and a striking form of a semi-reticulate *Productus* with narrow, highly-convex umbonal region, square-cut flanks, strong reticulation near the beak, and with the striæ thickened at intervals by spine-bases. This form seems to be near *P. doulaghensis*, Vaughan (Q.J.G.S., vol. lxxi, p. 47, pl. vii, fig. 7), but has straighter sides and a flatter venter.

The following also occur: *Dielasma* sp., *Athyris glabristria*, *Reticularia lineata*, *Spirifer pinguis*, *S. striatus*, *S. attenuatus*, *S. planatus*, *S.* cf. *convolutus*, *Camerophoria pleurodon*, *C.* (?) *tumida*, *Pugnax acuminatus* var. *plicatus*, *Orthotetes* sp., *Schizophoria resupinata* (large), *S. gibbera*, *Productus margaritaceus*, *P. cora*, *P.* cf. *concinnus*, *P.* "*pustulosus*", *Chonetes* aff. *comoides*.

The Gastropods belong to the genera *Euomphalus*, *Straparollus*, and *Phymatifer* (*Ph. pugilis*); *Bellerophon* also occurs; the Lamellibranchs are *Pterinopecten eximius*, *Pt. granosus*, and *Conocardium aliforme*.

With a few exceptions the assemblage of forms recalls, in part, the fauna of the "Brachiopod-beds" of the Midland area, allocated by Sibly to the sub-zone D_2 (*Lonsdalia* subzone), (Q.J.G.S., 1908).

Many of the forms occur in knolls of both Tournaisian and Viséan age, and are such as were regarded by Vaughan as indicating conditions only (Q.J.G.S., lxxi, p. 13). It would appear, from the abundance of *Productus humerosus* with such a fauna in Dove Dale, that this species has every right to be included as a knoll-form, and the species therefore loses its value as a zonal index. It is of interest to note that this species (as *P. sublævis*) is recorded from beds at Visé containing *Pugnax acuminatus* and *Phymatifer pugilis*. The massif at Visé is now regarded as equivalent to the "Brachiopod-beds" of the Midland.

The examples of the "early smooth form" of *Productus sublævis* (aff. *sublævis*, mihi) figured by Delépine and Vaughan are used by them as a zone-fossil indicating horizon δ—Basal Viséan. Such a course can only be reliable if the "smooth form" is unassociated with any other varieties.

It is hoped that further work in the Dove Dale area will result in defining the exact position of the "*Humerosus*-beds" with regard to the "Brachiopod-beds".

V.—British Association for the Advancement of Science, Bournemouth, 1919.

Address to the Geological Section. By J. W. Evans, D.Sc., LL.B., F.R.S., President of the Section.

ONE of the most striking features of our science is the need in which it stands of a large and widely distributed body of workers, and the opportunities which it affords to every one of them of making important contributions to scientific knowledge.

Every locality has its geological history stretching away into the "dark backward and abysm of time", and this history has left its records in the rocks of the earth's crust; an imperfect record, it is true, for much of it has long since been destroyed, but enough remains to reward long years of patient labour in deciphering it.

Everywhere some one is needed who will devote his spare time to the examination of the quarries and cliffs, where the materials that build up the solid earth are exposed to view, and who will record the changes that occur in them from time to time; for a quarry that is in work, or a cliff that is being undermined by the sea, constantly presents new faces, affording new information, which must be recorded if important links in the chain of evidence are not to be lost. It is equally important that some one should always be on the look-out for new exposures, road or railway cuttings, for instance, or excavations for culverts or foundations, which in too many instances are overgrown or covered up without receiving adequate attention. It is, again, only the man on the spot who can obtain even an approximately complete collection of the fossils of each stratum and thus enable us to obtain as full a knowledge as is possible of the life that existed in the far-off days in which it was laid down. In his absence many of the rarer forms which are of unique importance in tracing out the long story of the development of plants and animals, and even man himself, never reach the hands of the specialist who is capable of interpreting them. It was an amateur geologist, a country solicitor, who saved from the roadmender's hammer the Piltdown skull, that in its main features appears to represent an early human type, from which the present races of man are in all probability descended. Another amateur, who was engaged in the brick-making industry near Peterborough, has provided our museums with their finest collections of Jurassic reptiles. A third, a hard-worked medical man, was the first to reveal the oldest relics of life that had at that time been recognized in the British Isles; and

many more examples could be instanced of the services to geological science by those whose principal life task lay in other directions.

Such workers are unfortunately all too few—fewer, I fancy, now than they were before the pursuit of sport, and especially of golf, had taken such a hold upon the middle classes and occupied so considerable a portion of their leisure hours and thoughts. One might hope that the extended hours now assured to the working classes for recreation would lead to a general increase of interest in science among them, if it were not that the students of that admirable organization, the Workers' Educational Association, seem almost invariably to prefer economic or political subjects to the study of nature, a choice in defence of which they could no doubt advance most cogent arguments. In a large county in which I am interested the number of those in every condition of life who are able and willing to take part in geological research might be told almost on the fingers of one hand, and so far as I am aware there has not been a single recruit in recent years from the ranks of the younger men or women.

It seems strange that there are so few of our fellow-countrymen or countrywomen who feel a call to scientific research, especially in a subject which, like geology, makes a strong appeal to the imagination, telling us of the strange vicissitudes through which our world and its inhabitants passed before they assumed the guise and characters with which we are familiar. How few are there who realize that the prolific vegetation to which we owe our wealth of coal was succeeded after the lapse of incalculable years by far-stretching deserts, and these, after continuing for a period still longer in duration, were submerged beneath wide inland semi-tropical seas, under whose waters were accumulated the sediments of sand and mud and calcareous débris out of which the fertile valleys of Central England have been carved; or that the conditions under which we now live were only reached through the portals of bleak, desolate ages of excessive cold, the reasons for which we are still at a loss to understand.

Even if the appeal to the imagination were not a sufficient incentive to the cultivation of geology, one would have thought its economic importance would have been effective. Its intimate bearing on the problems of agriculture, engineering, water supply, and hygiene is too obvious to need emphasis here, and it is scarcely more necessary to point out that all our fundamental manufacturing activities, without exception, are dependent on adequate supplies of materials of mineral origin, so that we need not be surprised that one of the earliest administrative acts of the Imperial Conference was the constitution of an Imperial Mineral Resources Bureau to secure that the whole mineral resources of the Empire should be made available for the successful development of its industries.

It might be suggested that the prevailing indifference to the attraction of geological research was due to a conviction that after eighty years of work by the Geological Survey, as well as by University teachers and amateurs, there was little left to be done, and that all the information that could be desired was to be found in

the Survey publications. Such a belief can hardly be very widespread, for, as a matter of fact, comparatively few of the general public realize the value of the work of the Geological Survey, and still fewer make use of its publications. Municipal libraries, other than those of our largest provincial centres, are rarely provided with the official maps and memoirs relating to the surrounding areas, and in the absence of any demand the local booksellers do not stock them. This cannot be attributed to the cost, for though most of the older maps are hand-coloured and therefore expensive, the later maps—at least those on the smaller scales—are remarkably cheap, and the memoirs are also issued at low prices.

The true explanation appears to be that a geological map conveys very little information to the average man of fair education who has received no geological instruction. This is certainly not the fault of the Survey maps, which compare very favourably with those of other countries, and have been greatly improved in recent years. In particular, the introduction of a longitudinal section on each map and the substitution of the vertical section drawn to scale for the old colour index must greatly assist those into whose hands it comes in obtaining a correct view of the succession of the strata and the structure of the country. Some of the maps are, it is true, so crowded with information—topographical and geological—that it is frequently difficult, even for the trained geologist, to read them without a lens. This is largely due to the fact that they are printed over the ordinary topographical maps in which there is a great amount of detail that is not required in geological maps. In India the Trigonometrical Survey are always ready to supply, as a basis for special maps, copies of their own maps printed off plates from which a portion of the topographical features have been erased.

The best remedy, however, would be to extend the publication of the maps on a scale of 6 inches to a mile. For many years all geological survey work has been, in the first place, carried out on maps of this scale, but they have not been published except in coal-mining areas. There the geological boundaries are printed, but the colouring is added by hand, which makes the maps comparatively expensive. In other localities manuscript copies of the geological lines and colouring on the Ordnance Survey maps can be obtained at the cost of production, which is necessarily considerable. There is, I believe, a wide sphere of usefulness for cheap colour-printed 6 inch geological maps, especially in the case of agricultural and building land, for which the 6 inch Ordnance maps are already in demand. They afford ample room for geological information, and, accompanied by longitudinal sections on the same scale without vertical exaggeration, their significance would be more readily apprehended than that of maps on a smaller scale. It may be noted that this is the favourite scale employed by those engaged in independent geological research for their field work, and, when the area is not too great, for the publication of their results.

It would be of great advantage if there were a uniform usage by which the position in the stratigraphical series of rock outcrops were indicated by colour and their lithological character by stippling

(in black or white or colour), following the ordinarily accepted conventions. This course has been pursued by Professor Watts in the geological map prepared by him to illustrate his *Geography of Shropshire*. This increases the practical value of the map for many purposes, but is only possible when it is not overburdened with topographical detail.

Some explanation, apart from the maps themselves, is, however, needed if they are to be rendered, as they should be, intelligible to the general public. The official memoirs which deal with the same areas as the maps do not afford a solution of the difficulty. Excellent as they are from the technical standpoint and full of valuable information, they convey little to the man who has not already a considerable acquaintance with the subject. What is needed is a short explanatory pamphlet for each map, presuming no previous geological knowledge, describing briefly and in simple popular language the meaning of the boundary-lines and symbols employed, and the nature and composition of the different sedimentary or igneous rocks disclosed at the surface or known to exist below it in the area comprised in the map. A brief account of the fossils and minerals visible without the aid of a microscope should also be included. The probable mode of formation of the rocks and their relation to one another and the subsequent changes they have undergone should be discussed, and at the same time their influence on the agricultural value of the land and its suitability for building sites, as well as on the distribution and level of underground water, should be pointed out. Some account too should be given of the economic mineral products and their applications.

These pamphlets should be illustrated by simple geological sections, views of local quarries and cliffs showing the relative positions of the different rocks, figures of the commoner fossils at each horizon, and, where they would be useful, drawings of the forms assumed by the minerals. Each pamphlet would be complete in itself. This would involve a considerable amount of repetition, but it must be remembered that different pamphlets would have as a rule different readers. An alternative plan would be to follow the example of the United States Geological Survey and reprint the same brief résumé of geological principles in every case with such additions as are required to explain the meaning of individual maps. There can, however, I think, be no doubt that an explanation written expressly for each map can be made at once more easy to understand and more interesting to those without special geological knowledge.

That something further is required to render the information contained in the Geological Survey maps generally available to the public is illustrated by a correspondence that took place some years ago in one of our leading provincial papers with reference to the achievement of a manipulator of the hazel twig in discovering water in the Triassic rocks of the south-west of Derbyshire. No one seemed to realize that with the help of the Geological Survey map published forty years before and the contoured Ordnance Survey map more recently issued it was possible for anyone who possessed

a little geological knowledge and common intelligence to predict within narrow limits the depths at which it would be possible to find water at any point within the area under consideration.

When measures such as I have suggested have been adopted for rendering the publications of the Geological Survey easily comprehensible to the general public, it should be the policy of the Government to obtain for them the widest circulation, so that the information they contain should be generally known, a consummation not only desirable for its own sake as tending to increase the general interest in geology, but because it would be an important factor in developing the industries of the country.

During the War publications containing desirable information were circulated widely and gratuitously by the authorities to all public bodies concerned, and there seems no reason why the information laboriously gathered by the Geological Survey in the national interests and paid for out of the public funds should not now receive the same treatment. All Municipalities, District Councils, public libraries, colleges and schools, both secondary and elementary, should receive free copies of the Geological Survey publications dealing with the area where they are situated or with those immediately adjoining it.

When a new publication is issued the same measures should be taken to make it known locally as a private firm would employ; copies should be sent to the local press, which should be assisted to give an interesting and intelligible account of its contents, with a selection from the illustrations. There should also be a standing notice in the *Publishers' Circular* of the Survey publications, so that local booksellers may know where to apply for them. I am told that at the present they are sometimes completely ignorant on the subject.

Every facility should, of course, be afforded to the public to make use of the Survey publications. They should not only be on sale at the post offices in the areas to which they relate, but it should also be possible to borrow folding mounted copies of the maps as well as bound copies of the explanations and memoirs, on making a deposit equal to their value. When they were no longer required, the amount of the deposit, less a small charge for use, would be repaid on their return to the same or any other post office and the production of the receipt for cancellation. It would thus be possible, when traversing any part of the country, to consult in succession all the Geological Survey publications of the districts passed through. This system would also enable the permanent residents to refer to the more expensive hand-coloured maps, including the 6-inch manuscript maps, at a comparatively small cost.

The preparation and printing of the explanations of the Survey maps, and the increase in the numbers printed of other publications, would obviously involve additional expenditure. This would be to some extent set off by increased sales; but even if there were a net loss on the balance, it would be worth while if it enabled the fullest advantage to be taken of the expenditure incurred in any

event by the Survey in investigating the mineral resources of the country.

The Survey publications should be illustrated in every museum and school in the districts with which they deal by small collections showing the characters of the local rocks, and of the minerals and fossils that occur in them, and care should be taken to see that these collections are maintained in good order and properly labelled.

It would be a good plan for the Survey to appoint a local geologist, an amateur or member of the staff of a university or college, in every area of twenty or thirty square miles[1] to act as their representative and as a centre of local geological interest. He would be expected to give his assistance to other local workers who stood in need of it. He would receive little official remuneration, but inquirers in the neighbourhood would be referred to him, and where commercial interests were involved he would, subject to the sanction of the Central Office, be entitled to charge substantial fees for his advice. He would report to the Survey any event of geological importance in the area of which he was in charge—whether it was the discovery of a new fossiliferous locality, the opening of a new quarry,[2] the sinking of a well, or the commencement of boring operations. Many of these matters would be adequately dealt with by local workers, but in other cases it might be desirable for the Survey to send down one of their officers to make a detailed investigation.

One of the most important duties of the Survey, or its local representative, would be to see that the records of well-sinkings and borings are properly kept, and that where cores are obtained the depth from which each was raised is accurately recorded. At the present time the officers of the Survey make every effort to see that this is done, but they have no legal power to compel those engaged in such operations to give the particulars required. Equally important is a faithful record of the geological information obtained in prospecting or mining operations. This is especially necessary where a mine is abandoned.[3] If care is not then taken to see that all the information available is accurately recorded, it may never be possible later to remedy the failure to do so.

Probably these objects would be much facilitated if engineers in charge of boring or mining operations had sufficient knowledge of geology and interest in its advancement to make them anxious to see that no opportunity was lost of observing and recording geological

[1] I am afraid that in many parts of the country there are so few amateur geologists that this area would have to be increased, at any rate at first.

[2] It is very desirable that arrangements should be made for the co-operation of the Geological Survey or their local representatives with the Inspectors of Quarries appointed by the Home Office, and that the annual official list of quarries should describe the rocks which are worked, not only by their ordinary economic designations, but also by their recognized geological descriptions.

[3] Those engaged in mining are already required to furnish mining plans to the Mining Record Office, but there is no obligation to give any geological information that may have been obtained. This office was formerly attached to the Geological Survey, but was transferred some years ago to the Home Office.

data. This would be in most cases ensured if every mining student were required to carry out geological research as part of his professional training. It is now recognized that no education in science can be considered to be up to University standard if it is limited to a passive reception of facts and theories without any attempt to extend, in however humble a way, the boundaries of knowledge. In the case of geology such research will naturally in most cases take the form of observations in the field. The important point is that the work must be original, on new lines, or in greater detail than before, and not a mere confirmation of published results. It is only by the consciousness that he is accomplishing something which has not been done before that the student can experience the keen pleasure of the conquest of the unknown and acquire the love of research for its own sake.

At present it is disheartening to realize how few of those who have received scientific instruction understand the obligations under which they lie of themselves contributing to the growth of knowledge. If they have once had the privilege of achieving individual creative work they will henceforward desire to take advantage of every opportunity of continuing it.

There is one respect in which geological workers suffer a heavy pecuniary handicap—the cost of railway fares. This affects both the staff and students of colleges, as well as local workers who are extending their radius of work—an inevitable necessity in the investigation of many problems. It also seriously interferes with the activity of local Natural History Societies and Field Clubs, the Geological Societies and Associations of the great provincial towns, and, above all, that focus of amateur geological activity—the Geologists' Association of London. It is difficult to exaggerate the importance of these agencies in the promotion of geological education. Both professional and amateur geologists are deeply indebted to the excursions which are in most cases directed by specially qualified workers, with whom it is a labour of love. At the same time one of their most valuable results is the creation of interest in scientific work in the localities that are visited. Now that the railways are, if report speaks truly, to be nationalized, or at any rate controlled by the State, the claims of scientific work carried out without reward in the national interest to special consideration will surely not be ignored. All questions as to the persons to whom such travelling facilities should be extended and the conditions that should be imposed may safely be left to the decision of the Geological Survey, which has always had the most friendly and sympathetic relations with private workers and afforded them every facility and assistance, which their comparatively limited staff and heavy duties permitted.

It is impossible to speak in too generous terms of the Geological Survey[1] and its succession of distinguished chiefs (the last of whom, I am glad to say, is with us to-day), or of the work it has

[1] Since 1905 the Irish Survey, a small but enthusiastic band led by one of the most broad-minded of modern geologists, has been separated from that of the remainder of the country.

accomplished, in spite of somewhat inadequate financial support from the powers that be, who have taken every precaution that the Honours graduates who join its ranks should do so for the pure love of science and not for the sake of worldly advantage. With increased staff and less straitened finances the Survey would be in a position, not only to discharge the additional duties my suggestions would impose on them, but to extend still further the sphere of their usefulness. There is, for instance, at the present time a very urgent need for the provision of further facilities for the analysis of rocks and minerals to assist and complete the researches both of the official surveyors and of private persons engaged in research. The work is of a very special character, and the number of those who have given sufficient attention to it and understand its difficulties and pitfalls is very limited. The chemical staff at our Universities are chiefly concerned with organic chemistry, and private analysts devote themselves mainly to the examination of economic products. The effect of a hasty excursion of workers of either of these categories into the analysis of such complex silicates as augite or biotite or any of our ordinary igneous rocks is apt to be disastrous, only exceeded in this respect by the results obtained when, as not infrequently happens, a student is given a similar task by way of practice. A certain amount of good work is undoubtedly done in College laboratories, but it is very little in comparison with what is needed.[1]

At present the analytical work of the Survey is organized on a very modest scale in comparison with the personnel and equipment of the laboratory of the United States Geological Survey, though the quality of the work has been as a rule in recent years quite as high. There are two analytical chemists attached to the Geological Survey, and some of the other members of the staff are capable of doing good analytical work. The demand, however, for analyses for economic purposes is so great that it is impossible to carry out all the analyses that would be desirable in connexion with the purely scientific work of the Survey itself. There is consequently no possibility of their being able to assist private investigators.

Strictly speaking, the individual minerals of a rock should be separately analysed and their relative amounts determined, but this is at present a counsel of perfection that we cannot hope to attain; and when the difficulty of obtaining pure material, especially in the case of fine-grained rocks, and the zoned character of practically all complex rock-forming minerals are considered, it is seen that intrinsically it is not quite so important as it would seem to be at first sight. The bulk analysis, intelligently interpreted in connexion with the actual mineral composition of the rock as revealed by the microscope, is, in fact, at present the most practical method of determining the composition of the minerals. I need scarcely say that volatile constituents still retained by the rock should be separately

[1] I should like to refer in this connexion to the excellent analytical work of Dr. H. F. Harwood, of the Chemical Department of the Imperial College of Science and Technology.

determined, and the amount reported as water should not include any other substance given off at the same time.

In the absence of facilities for obtaining rock analyses, petrological work in this country is at present seriously handicapped. A striking illustration of the inadequate provision for analyses is revealed in the fact that for the whole of the early Permian granitic intrusions in the South-west of England, covering nearly 2,000 square miles, and including numerous different types and varieties, there are only four analyses in existence, and of these two are out of date and imperfect. This is all the more remarkable in view of the fact that these rocks are closely connected with the pneumatolytic action that has given us almost all the economic minerals of the South-west of England, comprising ores of tin, tungsten, copper, lead, and uranium, as well as kaolin. If the Survey, by increasing its staff of analysts, were in a position, not merely to multiply the number of analyses illustrating its own work, but to help others engaged in research, they would only be proceeding on lines which have long since been followed in some of our Dominions.

(To be continued.)

REVIEWS.

I.—Mountains. By C. A. Cotton, D.Sc., F.G.S. New Zealand Journal of Science and Technology, vol. i, No. 5, pp. 280–5, 1918.

IN this paper Dr. Cotton points out that the distinction commonly drawn between fold-mountains and mountains of circumdenudation needs qualification in those cases where the denudation is now in a second or later cycle, owing to superposition of block-structure with uplift on original folding. He considers that in many cases the erosion directly due to uplift was a comparatively short-lived process, and that the present mountains owe their elevation and relief to causes operating long after the folding had ceased. It is shown that certain of the mountains of New Zealand owe their present condition mainly to the Kaikoura orogenic movements, which were differential uplifts and not folding. New Zealand may, in fact, be described as a concourse of earth-blocks, the highest on the north-eastern and south-western axis of the land mass, and in places portions of the old marine plain of deposition can be recognized on the denuded surfaces of the uplifted and tilted blocks. This is an idea which has perhaps been insufficiently considered by physiographers, and the points raised are worthy of careful study, as they may be equally applicable to other regions.

II.—Observations on a Florida Sea-beach, with special reference to Oil Geology. By G. F. Kemp. *Economic Geology*, vol. xiv, pp. 302–23, 1919.

DURING a residence of two winters on the coast of Florida Mr. Kemp devoted a considerable time to the detailed study of the character and formation of the beach and the changes

produced in it by varying weather conditions; the special object in view was the comparison with the phenomena observed in oil-bearing strata, but the results obtained are of much interest to all physical and stratigraphical geologists. At Melbourne Beach, the place in question, a broad stretch of stagnant fresh water, without visible outlet, is separated from the open Atlantic by about half a mile of blown sand, covered with palmettos and other scrub; beneath this is everywhere found artesian water. The sands of the open sea-beach show several features of interest, including the ordinary types of ripple-mark due to winds and waves such as are so often preserved in older strata. The sloping part of the beach has an inclination as steep as 5°, and it is pointed out by the author that an ancient beach of similar slope, when exposed by denudation, might easily be mistaken for one limb of a fold. Under certain wind-conditions the beach sand is worked up into peculiar ridges called cusps by the author. They seem to be formed when the wind is straight on shore, and are destroyed by oblique surf-action. At times there are found in the sand numerous clots of asphalt; the origin of these is not yet understood, since they are apparently not connected with any local oil or bitumen occurrence, but appear to be washed up by the sea. Another feature mentioned is the occurrence of masses of a hard modern shell-limestone, called coquina; these are formed when a strong wind drives piles of shells into the hollows between the cusps; these accumulations are sometimes as much as a foot thick, and are soon hardened by cement deposited from percolating rain and sea-water. In course of time these will form small slabs and lenticles of limestone appearing abruptly in a coarse mechanical sediment, a puzzling feature when observed in the older rocks. Just below low-water mark the beach drops suddenly two or three feet and forms a distinct channel extending one or two hundred yards to the well-marked off-shore bar. This is the normal state of affairs, but occasionally under special weather conditions the bar moves inwards and coalesces with the beach, obliterating the channel. A description is also given of a very large shell-mound or kitchen-midden, showing layers of wood-ash and occasional bits of pottery. The mound is about 1,000 feet long, 50 feet wide, and 13 feet high in the middle. Other mounds larger than this are known in other parts of Florida, nevertheless this is impressive evidence of the activities of the earlier inhabitants of the region.

III.—Silver Spur Mine. Recent Development and Future Prospecting. By L. C. Ball. Queensland Geological Survey Publication No. 264. pp. 36, with 10 figures. Brisbane, 1918.

THIS mine, which is situated near the boundary between Queensland and New South Wales, on the Darling Downs, lies in metamorphosed sediments and tuffs of Permo-Carboniferous age. The ore bodies are found for the most part in crash zones in slate, and consist of masses and disseminations of mixed sulphides, with a gossan and oxidized zone at higher levels. The metals yielded are

silver, lead, zinc, copper, with about 1 dwt. of gold per ton. The distribution and paragenesis of the ores is of interest, since a definite sequence is shown, with copper nearest the surface, followed by galena, blende, and arsenopyrite successively in depth. The whole thickness of the zone series is here unusually small, amounting to only about 500 feet, and it is an interesting subject for speculation as to what metal, if any, may be found at greater depths. The origin of the ores is here referred to an underlying igneous intrusion, probably connected with a dyke of diorite outcropping in the neighbourhood of the mine, though it has also been attributed to the influence of the Stanthorpe massif, which, however, appears to be at too great a distance.

IV.—On the Origin of Septarian Structure. By W. A. Richardson. Mineralogical Magazine, vol. xviii, pp. 327–38, 1919.

In spite of much discussion of the mechanism of septarian structure, the subject has hitherto remained obscure, largely for want of experimental evidence. It is here shown that the common description of radial cracks widening towards the centre is inaccurate and misleading, since the true structure is usually polygonal in section and the width of the cracks is independent of their position in the nodule. A section thus reproduces very closely the appearance of a film of clay allowed to dry on glass. The arrangement of the cracks is compared with the various types seen in drying timber, while experiments were also made with spheres of mud coated with Portland cement and immersed in salt solutions. This process produced a very good imitation of septarian structure, and it is concluded that the cracking of the nodules is due to chemical desiccation of a colloidal centre, while the nodules themselves originated by the rhythmic precipitation of solutions diffusing through a colloid according to the principles laid down by Liesegang: the material thus precipitated was probably formed by gradual accumulation of bicarbonates by the action of organic by-products on compounds of lime or iron in the rock. It is frequently stated that fossils are commonly found at the centres of septaria, but this occurs with comparative rarity; the majority of those examined contained no fossils at all, and when present they were rarely central. On the other hand many fossils occur in the immediate neighbourhood of barren concretions.

V.—The Keweenaw Fault. By A. C. Lane. Bull. Geol. Soc. Amer., vol. xxvii, pp. 93–100, 1916.

The great fault which forms the southernside of the copper-producing region is of considerable economic and structural interest. In this paper the author shows that it probably began as a block-fault and was also a line of volcanic activity. In the hollow bounded by the fault-scarp the Upper Keweenawan beds were deposited and appear to shade into the Eastern Sandstone of Upper

Cambrian age. After three more Palæozoic marine transgressions, thrust-faulting occurred at the time of the Appalachian Revolution, carrying Keweenawan beds over the Lower Palæozoic. The present land-surface is probably due for the most part to Cretaceous denudation, which has exposed the outcrops of both principal faults at different points.

VI.—Notes on the Placer Mines of Cariboo, British Columbia. By J. B. Tyrrell. Econ. Geol., vol. xiv, pp. 335–45, 1919.

THE importance of alluvial mining for gold in the valleys of the Cariboo district of British Columbia has led to a careful investigation and survey of the drainage system of this remote region, revealing features of considerable interest to the student of river development. An important feature of the region is the existence of auriferous gravels of pre-Glacial age, in some instances deposited by streams whose courses have been seriously modified at a later date. Many of these gravels are now deeply buried under boulder-clay and other glacial deposits. Some of the upper tributaries of the Willow River in the neighbourhood of Mount Agnes show very clear examples of capture and beheading, and in some cases the present creeks have cut narrow gorges in the floors of wide open valleys belonging to an earlier arrangement of the drainage. The present stream system in the neighbourhood of Barkerville, as shown in the small sketch-map given by Mr. Tyrrell, is a particularly striking case of diversion. Although some of the smaller changes seem to be due to the deposition of boulder-clay it would appear that the larger modifications have been brought about more by piracy in pre-Glacial times than by moraines or other barriers of Glacial age.

VII.—Platinum Metals in the Somabula Diamondiferous Gravels. By H. B. Maufe. Southern Rhodesia Geological Survey. Short Report No. 5, 1319.

THE Somabula Diamondiferous Gravels which contain the diamond and numerous gemstones are found almost on the main watershed of Southern Rhodesia close to Willoughby's Siding and about 12 miles south-west of Gwelo.

An examination of the pebbles composing the gravels revealed the presence of chromite and chromite-bearing rocks in appreciable quantity: and therefore the possibility that the rocks might contain platinum or metals of the platinum group (iridium, osmium, palladium, rhodium, and ruthenium).

The late Mr. Zealley, in writing of the occurrence of platinum in Southern Rhodesia, said: "The Somabula gravel for instance is a likely source, since it is known that much heavy material is concentrated therein, and that a considerable proportion of the pebbles are from ultra-basic rocks; thus pebbles of chromite rock are abundant, and many of the chalcedony pebbles can be recognized by the practised eye as silicified serpentines derived from the Great Dyke and from the ancient schists. The fine heavy black gold-bearing sands concentrated from the Somabula gravels apparently

have not been examined for platinum. The finest material should preferably be tested."

A sample of the heaviest fine concentrate obtained in the washing for diamonds was sent to the Imperial Institute to be assayed for platinum metals, and the Director reports the following results:—

	Per ton of concentrate.	
	oz.	dwt.
Platinum	3	12
Osmiridium	7	0

He also reports: "Palladium was probably present, but the quantity was too small to be definitely identified. The concentrate also contained a large amount of gold."

VIII.—The Tertiary Geology of Devon and Cornwall. By H. J. Lowe. Trans. Devon. Ass. Adv. Sci., etc., 1918, pp. 391–401.

THE author reviews and discusses the conclusions reached by the Geological Survey and other authorities as to the Tertiary history of the Devono-Cornish peninsula, with special reference to the age and origin of the high-level plateaux and the courses of the Tertiary rivers. He criticizes the views put forward by others, but has little to offer in the way of alternatives. He does, however, suggest that the plateaux may in part be due to the peculiarly uniform and resistant character of the rocks composing them which renders them equably resistant to denudation over large areas: no evidence is brought forward in support of this hypothesis. It is estimated that the excavation of the Teign valley to its present depth occupied no less than 3½ million years, while a further argument concerning the age of the limestone caverns is not very clear, and its bearing on the point at issue is not obvious.

REPORTS AND PROCEEDINGS.

I.—Titles of Papers, etc., read at Meeting of British Association in Section C, Geology (and in other Sections bearing upon Geology), Bournemouth, September 9, 1919.

Presidential Address by *Dr. J. W. Evans, F.R.S.*

Dr. W. T. Ord.—The Tertiary Rocks of the Hampshire Basin.

Professor S. H. Reynolds.—The Lithological Succession in the Avonian of the Avon Section, Clifton.

Reports of Committees.

Excursion to Bournemouth Cliffs.—Leader, Dr. W. T. Ord.

Sir Aubrey Strahan, K.B.E., F.R.S.—The Mesozoic Rocks of the Bournemouth District.

Joint discussion with Section H (Anthropology) in the Rooms of Section C.—The Post-tertiary Geology of the District with special reference to the Flint Implements contained in them. *Mr. Reginald Smith* introduced the discussion, and his communication was illustrated by a collection of flint implements specially loaned for this occasion.

Mr. Henry Bury.—The Origin of the Bournemouth Chines.

Dr. W. E. Miller.—The Pre-Cambrian of Central Canada.

Dr. J. W. Evans, F.R.S.—The Correlation of the Marine Devonian of the United Kingdom with that of other Countries.
Dr. M. C. Stopes.—The Mesozoic Flora of the Bournemouth District.
Dr. W. T. Ord.—Bournemouth Bay and its Erosion.
Reports of Committees.
Excursion to Barton and Hordle Cliff.
Excursion to Swanage.—Leader, Sir Aubrey Strahan.
Excursion to Lulworth.—Leader, Sir Aubrey Strahan.
Excursion to Corfe.—Leader, Dr. W. T. Ord.
Excursion to Kimmeridge and Neighbourhood.—Leader, Mr. J. Pringle, H.M. Geological Survey.

PAPERS READ IN OTHER SECTIONS BEARING ON GEOLOGY.

SECTION D (ZOOLOGY).

Mr. C. Tate Regan, F.R.S.—The Geographical Distribution of Freshwater Fishes, with special reference to the past history of Continents.
Mr. D. M. S. Watson.—Palæontology and the Evolution Theory.
Joint meeting of Section C with Section D (Zoology) in the Rooms of Section C.
Excursion to Corfe.—Leader, Dr. W. T. Ord.

SECTION K (BOTANY).

Presidential Address by *Sir Daniel Morris, K.C.M.G.*
Dr. D. H. Scott, F.R.S.—The Relation of Seed Plants to the higher Cryptogams.
Dr. M. C. Stopes.—Plants in relation to the four parts of true Coal.
Mr. E. Heron-Allen, F.R.S., and *Mr. A. Earland.*—A Study of the Foraminiferal Species *Verneuilina polystropha* (Reuss), and some experiments in its cultivation in hypertonic sea-water and gem-sand.
Mr. H. Moncton.—The Flora of the District of the London Clay.

II.—ABSTRACTS OF PAPERS READ BEFORE THE BRITISH ASSOCIATION (SECTION C, GEOLOGY) AT BOURNEMOUTH, 1919.

1. THE POST-TERTIARY DEPOSITS OF THE BOURNEMOUTH AREA. By REGINALD A. SMITH.

The temporary exhibition of palæoliths from the Bournemouth district suggests further inquiry into the age and character of the beds in which they are found. Gravel is widely distributed over the high ground between the Stour and the coast at about 100 feet O.D., and the implements are often found at the base of deep deposits in an unrolled condition, and therefore presumably in situ. The current view is that the gravels were laid down by a great river flowing eastward between the present coastline and a southern bank connecting the Needles with the Isle of Purbeck; but in view of similar discoveries on St. Catherine's Hill (between the Avon and Stour and close to their junction), it seems likely that the Bournemouth gravels were originally continuous with those of the New Forest, and that the implements were embedded in them before the present valleys of the Stour and Avon were deeply cut. Several

implements have been found in high and low gravel-beds in the New Forest, and coast finds are abundant from Poole Harbour to Southampton Water. A section from Bramble Hill south-west to the coast is given in Proc. Geol. Assoc., xxvi (1915), 4, suggesting that the implement-bearing beds are part of a plateau deposit rather than the terrace-gravel of a Solent river.

2. The Chines of Bournemouth. By Henry Bury, F.G.S.

The country round Bournemouth consists of an almost level plateau, intersected by numerous valleys, and some of the latter, running down to the sea, are of a precipitous character, and are distinguished under the name of "Chines". They are usually described as having started as small gullies in the face of the cliff and having worked back inland; but the evidence seems to be against this. Not only is there no sign of special activity at their heads, but each is found to consist of an older valley with a U-shaped section, and a newer one, shorter and narrower, shaped like a V. The older valleys probably joined the Frome–Solent River about 1–2 miles from the present shore-line; the newer ones owe their smaller size to reduction in water-supply, and their steepness to the rapid retreat of the shore-line under marine action. They are in fact growing shorter, and not longer, and the final obliteration of some of them may have helped to give rise to the belief that the cliffs themselves are growing steeper.

3. The Lithological Succession in the Avonian of the Avon Section, Clifton. By S. H. Reynolds, Sc.D., F.G.S.

Several previous workers have dealt with the lithology of the Avon section, and in particular Mr. E. B. Wethered and the late Dr. A. Vaughan. The results of the present paper are based in part on field work, in part on the study of over 200 rock slices which have been cut with the aid of grants from the University of Bristol Colston Society.

The chief rock-types occurring are the following, the horizons being alluded to under the designation adopted in Vaughan's original paper.[1]

Calcareous Rocks.

Algal Limestones are abundant (*a*) in Km, (*b*) at the top of C_2, (*c*) in the lower part of S_1, (*d*) in the pisolitic beds of the lower part of S_2, (*e*) in the "Concretionary Beds" of the upper part of S_2: this is the most important development.

Mitcheldeania and *Solenopora* are the most persistent forms ranging from the base of K to the top of S_2. *Spongiostroma* is the prevalent form in the calcite-mudstones which are so abundant in C_2 and S.

Foraminiferal Limestones: Foraminifera first began to be fairly common in Z_2. They occur in great abundance in the upper part of S_2 and the lower part of D_1.

Coral Limestones: Zaphrentid corals play an appreciable part as limestone builders in Z_1, while bands full of *Lithostrotion martini* are

[1] Q.J.G.S., vol. lxi, 1905.

most characteristic of S. Corals attain their greatest importance in D.

Crinoidal Limestones: Crinoids are abundant in K_1 and K_2, and are the greatest limestone builders throughout the whole of the Z beds.

Brachiopod Limestones are met with throughout nearly the whole section. *Spirifer*, *Orthotetes*, and *Chonetes* being the most abundant Tournaisian genera, *Seminula*, *Productus*, and *Chonetes* the commonest Viséan.

Ostracods are very plentiful wherever the rocks are shaly or of the calcite-mudstone type, viz.: throughout K, at the top of C_2, and in the lower part of S_1.

Oolites occur at the following levels: (*a*) in the upper part of C_1, (*b*) in the middle of S_2, (*c*) throughout D.

Siliceous Rocks.

Grits are met with only in the D beds. Chert bands occur (*a*) near the middle of Z_1, (*b*) in S_2 below the oolite, (*c*) in S_2 between the oolite and the "Concretionary Beds".

Argillaceous Rocks.

Thick shales are met with (*a*) throughout K_1, (*b*) in upper C_2 and lower S_1, (*c*) in upper D_1 and upper D_2.

Changes which have affected certain of the rocks. *Penecontemporaneous brecciation* (desiccation breccias) are characteristic of all the shallow water (lagoon-phase, Dixon) rocks of C_2 and S.

Dolomitization proves to be considerably more widespread in the Avon rocks than had been previously supposed. The matrix of the *Petit Granit* of Z_1, Z_2, and γ is almost everywhere dolomitized. The almost complete dolomitization of C_1 and the upper part of C_2 has long been familiar. There has been considerable dolomitization in the calcite-mudstones of S_1 and lower S_2. All the chief dolomites are to be classed as contemporaneous according to the classification of Mr. L. M. Parsons.[1]

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4. The Pre-Cambrian of Central Canada. By Willet G. Miller.

Ten years ago, at the Winnipeg meeting of the British Association, the author presented a paper dealing with the age relations of the pre-Cambrian rocks of Canada. Since then much field work has been done in connexion with these rocks, not only in the province of Ontario, but to the eastward in Quebec and, to a lesser extent, to the westward in Manitoba and Saskatchewan. There has been great mining activity in the pre-Cambrian areas of Ontario, which has afforded special facilities for study to the geological staff of the Ontario Bureau of Mines. From time to time papers and reports have been published as our knowledge has increased, and the age classification has been revised.[2] The following classification is now employed by the Ontario Bureau[3]:—

[1] Geol. Mag., Dec. VI, Vol. V, p. 246, 1918.

[2] *Ont. Bur. Mines*, vol. xix, pt. ii; vol. xxii, pt. ii.

[3] *Journal of Geology*, vol. xxiii, No. 7.

PRE-CAMBRIAN.

KEWEENAWAN	
Unconformity	
ANIMIKEAN	Under this heading are placed not only the rocks that have heretofore been called Animikie, but the so-called Huronian rocks of the "classic" Lake Huron area, and the Cobalt and Ramsay Lake series. Minor unconformities occur within the Animikean.
Great unconformity	
(ALGOMAN granite and gneiss)	Laurentian of some authors, and the
Igneous contact	Lorrain granite of Cobalt, the Killarney granite of Lake Huron, etc.
TIMISKAMIAN	In this group are placed sedimentary rocks of various localities that heretofore have been called Huronian, and the Sudbury series.
Great unconformity	There is no evidence that this unconformity is of lesser magnitude than that beneath the Animikean.
(LAURENTIAN granite and gneiss)	
Igneous contact	
LOGANIAN — Grenville (*Sedimentary*) / Keewatin *Igneous*	The Grenville limestones, with more or less greywacke, quartzite, and iron formation or jaspilyte at the base, were deposited on the Keewatin lavas.

It will be noted that the historic name "Huronian" has been discarded. Much confusion has arisen through the employment of this name, especially with the prefixes Upper, Middle, and Lower, in different senses. The term "Lower Huronian", for example, has been applied indiscriminately to certain rocks that lie below one of the greatest known unconformities—that between the Timiskamian and Animikean in the table—as well as to some of those above it. When making use of the term "Huronian", in order to secure clearness, it has been necessary to say in what sense it is employed, whether in that of the United States Geological Survey or in that of various writers on the subject.

Logan first studied the rocks, to which he afterwards gave the name "Huronian", on the shores of Lake Timiskaming. There are two series of conglomerates and other fragmental rocks here, separated by a great unconformity, which was discovered only when the geology of the Cobalt area was worked out. The lower series belongs to the Timiskamian of the table and the other to the Animikean.

The age relations of another historic series, the Grenville, have also been determined only during recent years. Most authors had suggested that the Grenville belonged to the so-called Huronian

group of sediments, but it has proved to be the oldest sedimentary series. The Keewatin rocks, essentially schists and greenstones, represent, for the most part, submarine lava-flows. On the surface of these flows were deposited the Grenville sediments. While the major part of the Grenville is later than the major part of the Keewatin, a minor part of one group is contemporaneous with a minor part of the other. It is remarkable that among the oldest series of Australia, India, Africa, and other countries are rocks that resemble very closely the Keewatin of Canada, with its associated iron formation or jaspilyte.

Among most of the workers on the pre-Cambrian of North America there is now general agreement as to the age relations of the rocks, but different classifications and nomenclatures are employed. Most authors make a dual subdivision of the pre-Cambrian which seems to the author to be purely arbitrary and based on a misconception. There is no proof that the unconformity at the base of the Timiskamian is of less magnitude than that at the base of the Animikean, or vice versa.

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5. The Plant-bearing Cherts at Rhynie, Aberdeenshire.—Report of the Committee, consisting of Dr. J. Horne (Chairman), Dr. W. Mackie (Secretary), and Drs. J. S. Flett, W. T. Gordon, G. Hickling, R. Kidston, B. N. Peach, and D. M. S. Watson, appointed to excavate Critical Sections therein.

The plant-bearing cherts discovered by Dr. Mackie in the Old Red Sandstone at Rhynie, Aberdeenshire, when examined under the microscope, showed fragments of Crustacea in certain sections. Some of the sections were submitted to Dr. W. T. Calman and Mr. D. I. Scourfield, who have furnished the following report: "The animal remains are, for the most part, very fragmentary and confused, but they are in an excellent state of preservation, even the fine feathering on small setæ being, in some cases, easily recognizable. All the remains examined appear to be referable to the class Crustacea, and to have belonged to animals comparable in size to the Copepoda of the present day. The most complete portions hitherto found have been tails, consisting each of a number of segments and ending in a furca. Both lateral and dorsal views have been seen, and the general arrangement of the parts fairly well made out. Two distinct species appear to be represented, belonging either to a primitive group of the Copepoda or to the very small Branchiopoda (? Anostraca). Fragments of appendages are numerous in nearly all the slides, but are extremely difficult to interpret. One slide, however, shows a series of about three pairs of biramous feet in their natural connexions. They are remarkably similar to the swimming feet of Copepods of the genus *Cyclops*, except that the branches are unjointed instead of being composed of the usual three segments. A considerable number of detached mandibles have also been seen, all of them most closely comparable to those of the Branchiopoda. It is evident that these remains are of extraordinary interest, and, although little progress has been made towards reconstructing any

one of the several species that are represented in the material, enough has been done to show that, given a sufficient number of sections, the structure of the body and limbs could almost certainly be worked out, even if no entire specimens should be brought to light."

During 1918 Mr. D. Tait, H.M. Geological Survey, obtained additional specimens of chert from the Rhynie outcrop, to be examined by Dr. Calman and Mr. Scourfield. A grant from the Royal Society has been received to aid the investigation.

III.—Edinburgh Geological Society.

March 19, 1919.—Mr. John Mathieson, F.R.S.G.S., Vice-President, in the Chair.

1. "Acid Potassium Sulphate as a Petrochemical Test and Solvent." By Dr. Wm. Mackie, M.A., Elgin.

An abstract of this paper was given by Dr. Campbell. It is a record of a comprehensive research on the action of acid potassium sulphate as a petrochemical test and solvent, as applied to the study of residues of heavy minerals in Scottish granite, and sedimentary rocks. These residues when acted upon by this solvent, in a state of fusion, displayed certain changes in colour, characteristic etching marks, and other phenomena by which they could be readily distinguished under the microscope. Dr. Mackie describes certain methods of treating these mineral residues, and subsequently mounting them on microscopic slides for study and recognition.

2. "Chemical Analysis of the Dolerite and Hornfels of Auchinoon." By Mr. T. Cuthbert Day, F.C.S.

This paper gives a record of eight complete chemical analyses of the rocks of Auchinoon, including the intrusive dolerite and the overlying hornfels with which it is in contact. The differences in the appearance and composition of the dolerite as found about 10 feet below the junction, and at the junction itself, were pointed out, and also the variations in the analyses of the hornfels at the junction itself and at increasing distances from it. An analysis of the clay band overlying the hornfels was also given.

IV.—Liverpool Geological Society.

The annual meeting of this Society, inaugurating the Sixty-first Session, was held at the Royal Institution, Liverpool, on October 14, 1919. Mr. W. T. Walker, B.Sc., F.G.S., was elected President, and Professor P. G. H. Boswell, O.B.E., D.Sc., F.G.S., Vice-President.

The retiring President, Dr. J. C. M. Given, F.G.S., delivered an address on "The Divisions of the Pleistocene", which was devoted to a review and criticism of the results of recent work on this latest period of geological history. For the purpose of subdividing the epoch, palæontological methods might be employed, and the mammalian fauna enabled three distinct life zones to be defined, viz.: (1) that of a warm climate represented by *Elephas antiquus*; (2) that of a cold climate with *E. primigenius*, etc.; and finally (3) that of a more genial climate with *Rangifer tarandus* and *Cervus giganteus*. These faunal divisions are useful, but they overlap very much, and are not numerous or sharp enough to be of great scientific